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WEEKLY 13 May 2023

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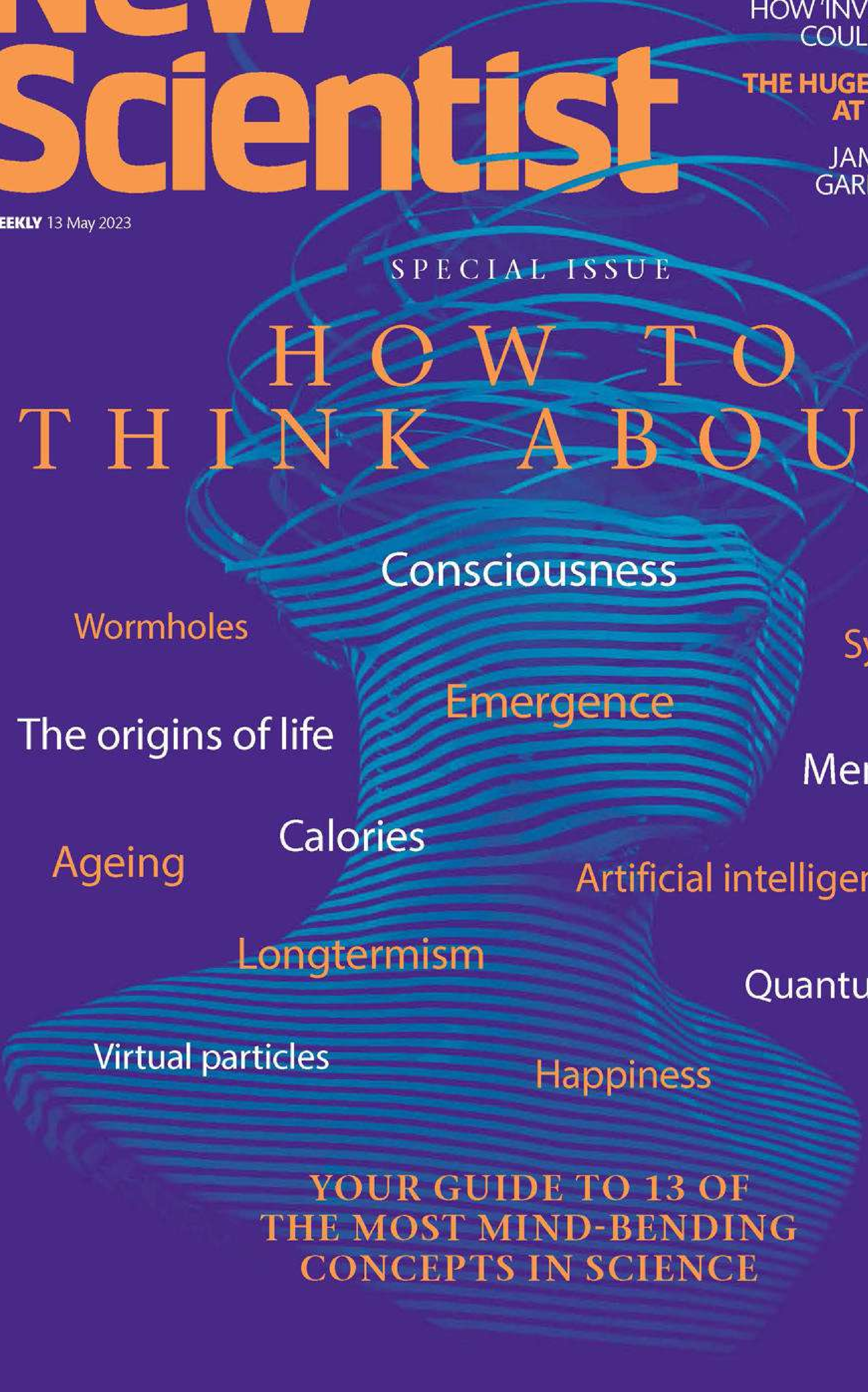
THE HUGE LEGAL PROBLEM AT THE HEART OF AI

JAMES WONG'S NEW GARDENING COLUMN



SPECIAL ISSUE

HOW TO THINK ABOUT...

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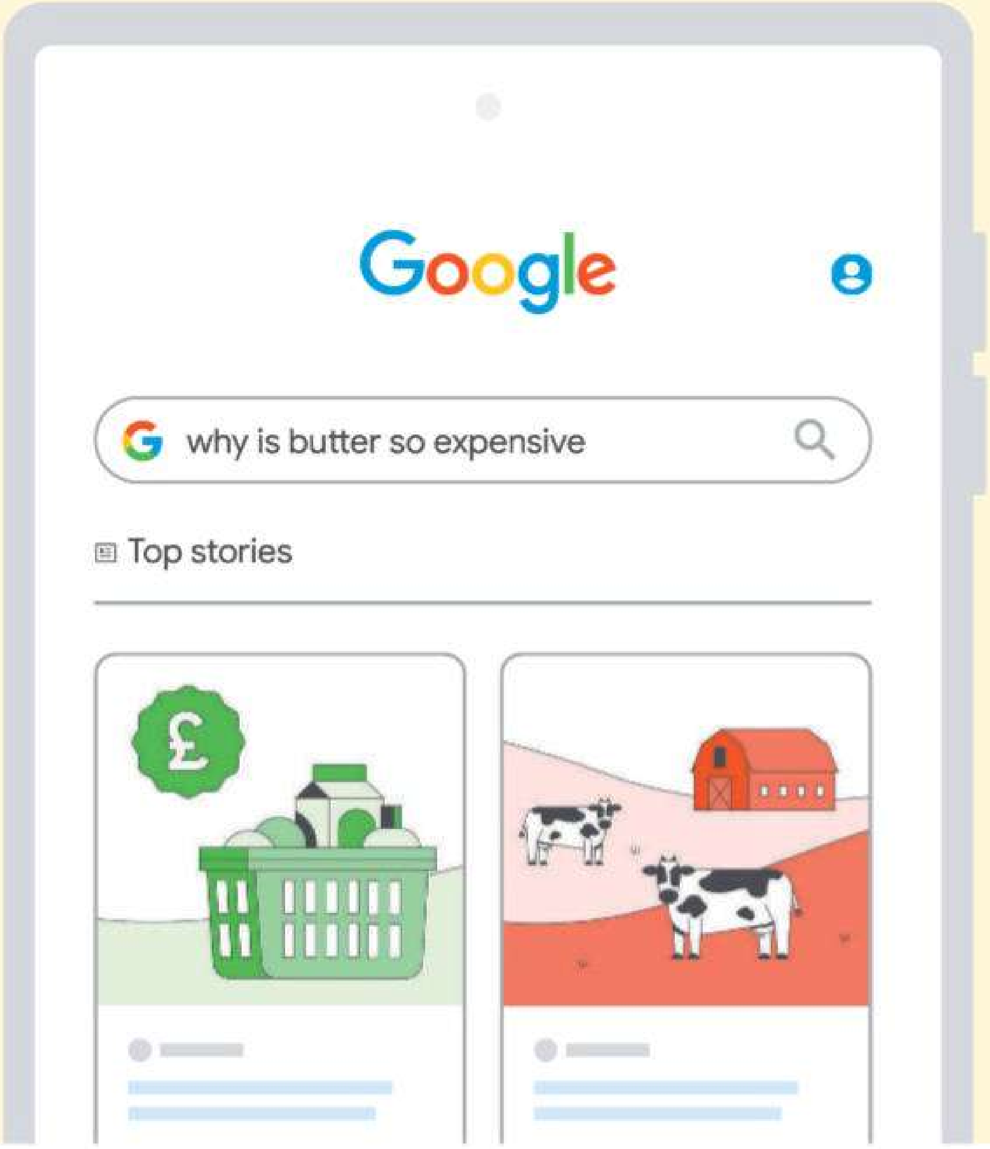
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Where and when did life on Earth originate? How do artificial intelligences "think"? What is the secret to happiness? How is consciousness generated? The most fascinating concepts in science are also among the most difficult to get your head around. Our clear-eyed guide offers perspectives on how experts think about 13 of the most mind-bending ideas

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Virtual event

Opening the Infrared Treasure Chest with the James Webb Space Telescope

Join Nobel prizewinning astrophysicist John Mather as he discusses how NASA and its partners built the James Webb Space Telescope – and learn about the discoveries made since it began its science operations last year. Watch online at 6pm BST/1pm EDT on 17 May. Tickets are £16.

newscientist.com/events

Tour

Science of the Arctic expedition cruise: Norway

Explore the land of the midnight sun on this tour of the Svalbard archipelago. Accompanied by *New Scientist*'s Rowan Hooper, you will visit peaceful fjords and glimpse local wildlife including beluga whales and polar bears. Shore visits are complemented by a programme of talks. The 13-day tour begins on 18 June 2024. Tickets from £9995.

newscientist.com/tours

Podcast

Weekly

One genome is enough for most organisms, but a single-celled alga has seven. The team finds out why. There is also news of a signal recorded in the brains of people just before they died that might help explain near-death experiences. Plus, in the CultureLab podcast, there is an interview with Peter Wohlleben, author of *The Power of Trees*.

newscientist.com/nspod

NASA/ESA/CSA

Clear view A James Webb Space Telescope image of the M74 galaxy

KRIS GRABIEC/SHUTTERSTOCK

Icy wonderland The spectacular scenery of Svalbard

Video

Robo-seal

Seals aren't the most graceful animals on land, but their bounce-and-lunge approach to locomotion has inspired researchers to build a robot that moves in the same way. There is footage of the curious robot on our YouTube channel this week. Its designers say similar robots could help in rescue missions where wheeled versions would struggle.

youtube.com/newscientist

Newsletter

Lost in Space-Time

The dark night sky tells us a lot about the universe, writes Nobel prizewinning astrophysicist Adam Riess. Night should be as bright as day, assuming an infinitely large and eternal universe, because light from stars would reach us from every direction. But darkness fits with the idea of a finite universe.

newscientist.com/lost-in-space-time

Podcast

> **"Just before the people died, there was brain activity that may indicate a conscious mind"**

Essential guide

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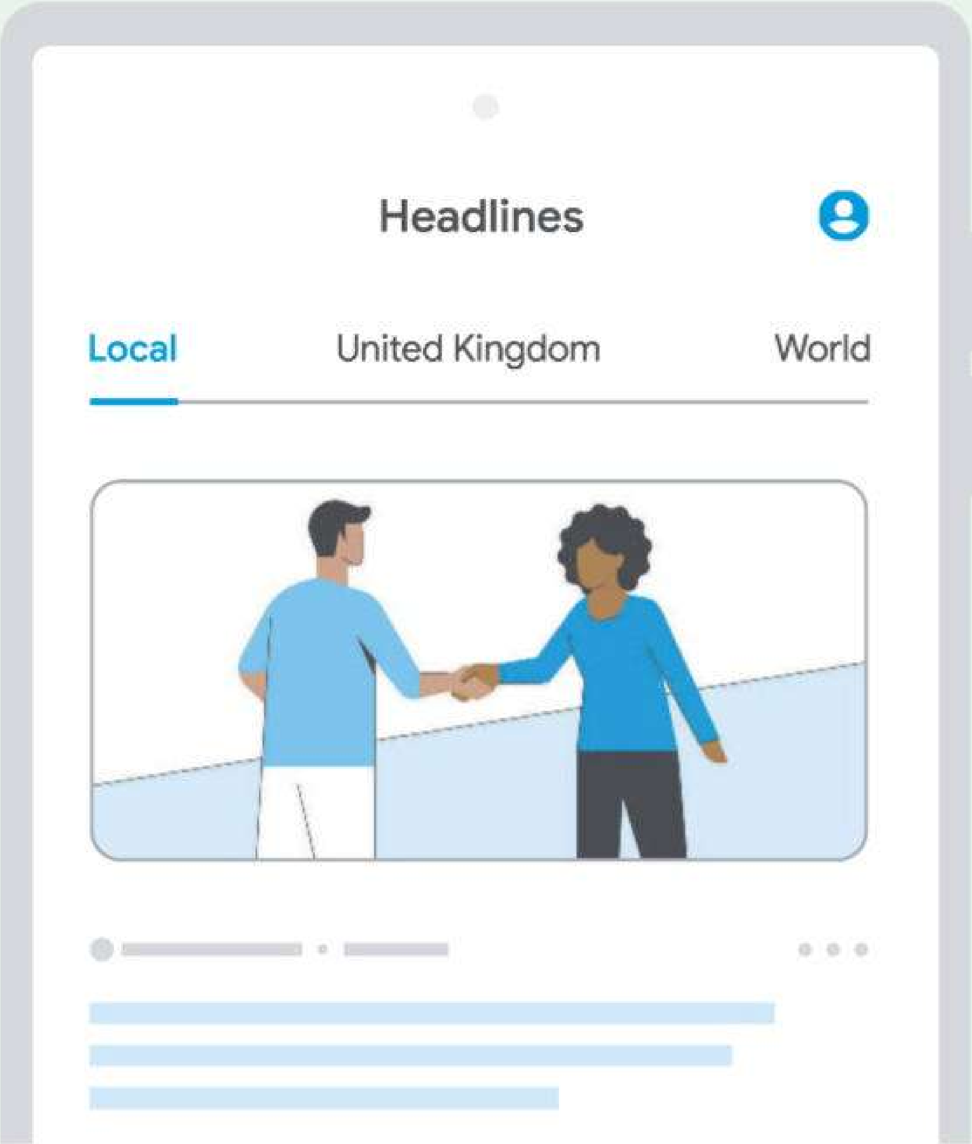

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Pay up, please

When it comes to artificial intelligence exploiting data, who will foot the bill?

LIKE most *New Scientist* readers, you are probably a human. But, increasingly, publications like ours have a new breed of artificially intelligent consumers – an apt word, because these AIs don't so much read as they do ingest, gobbling up vast quantities of text as part of their training.

Our human readers (we hope) derive value from reading *New Scientist*, whether that be for our informative news, mind-bending features, smart commentary or fiendish puzzles. In return for that value, all we ask is that you buy the magazine, subscribe digitally or even just let us show you a few ads. It seems a fair trade.

AI readers, or rather the researchers and companies behind them, also derive value from *New Scientist*. In a way, every piece of content consumed by an AI becomes a part of it, frozen in the numerical values that make up its neural networks. With this in-built knowledge, AIs like ChatGPT can spew out all sorts of text on command.

But *New Scientist* isn't compensated for this value provision. As far as we know, no AIs have taken out a subscription. Yet the C4 data set, an enormous collection of 750 gigabytes of text used to train many AIs, contains around 7 million words or phrases derived from *New Scientist* content. You can also find great swathes of data from *The New York Times*, *The Guardian* and many other publications.

> "With the latest AIs set to overturn entire industries, it is time to figure out who pays for the data"

This, we believe, isn't a fair trade – and we aren't alone. Everyone from Twitter CEO Elon Musk to small website owners is increasingly feeling hard done by when it comes to AIs exploiting their data (see page 12).

What isn't yet clear is the solution. When you, a human, read these words, you aren't infringing *New Scientist*'s copyright, even if you have a perfect memory. But it is unclear whether AIs ingesting copyrighted material en masse could be subject to legal action (see page 13). The use of text to train AIs is nothing new, and until now no one has really cared about copyright because it was all small-scale research. With the latest generation of AI set to overturn entire industries, it is time to figure out who pays. ▮

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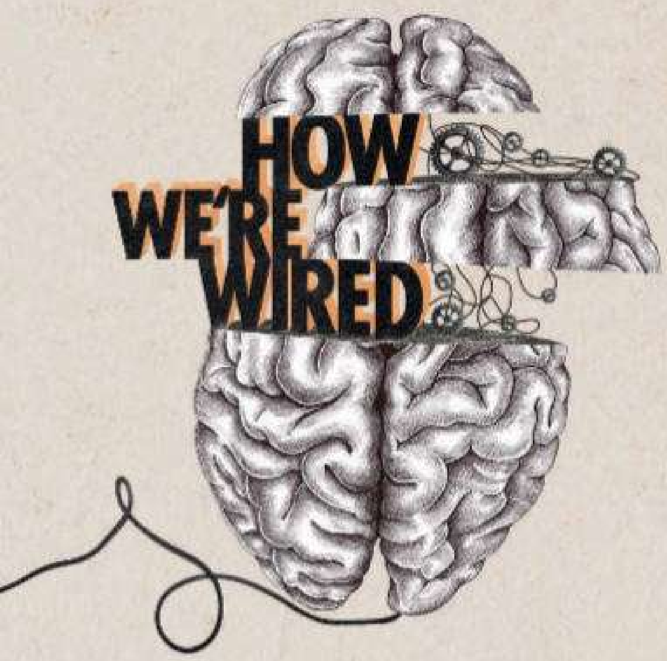
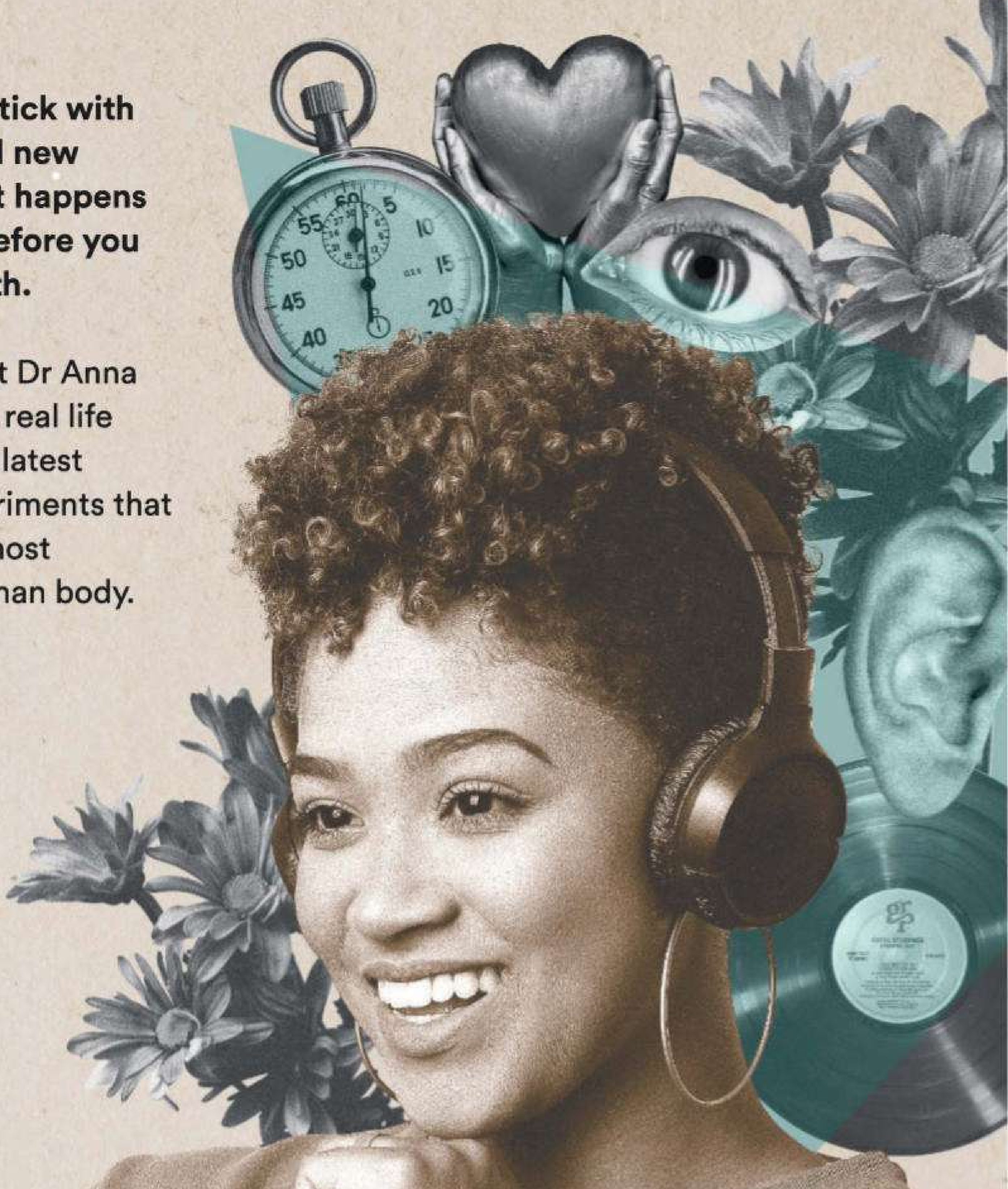
OWN YOUR MIND BUSINESS

Discover what makes you tick with How We're Wired, a brand new podcast that looks at what happens inside your brain – from before you were born through to death.

Presented by anthropologist Dr Anna Machin, this series features real life stories, expert analysis, the latest research and at-home experiments that will open your eyes to the most fascinating organ in the human body.





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News

First stars
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Wild behaviour
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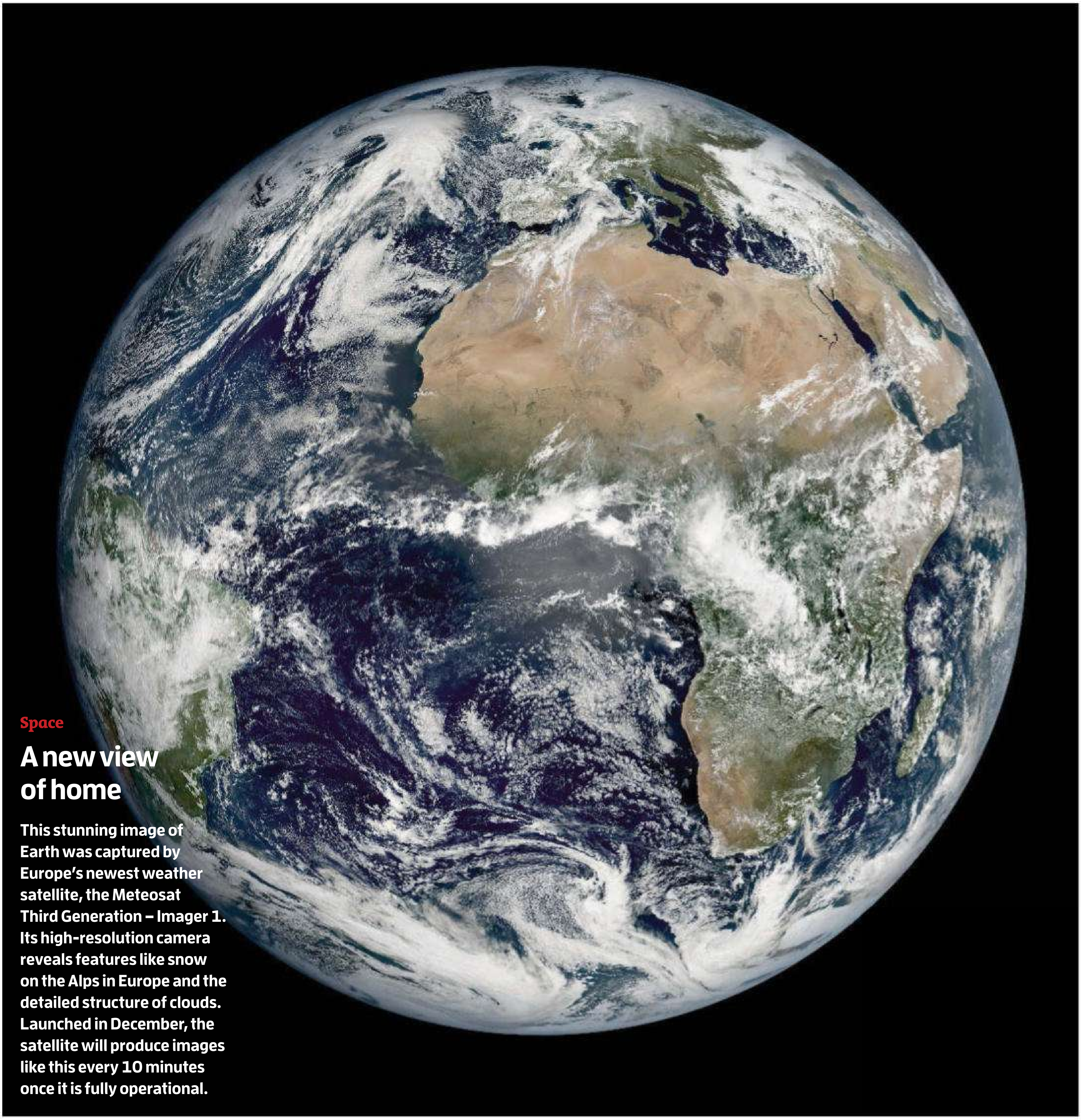


Space

A new view of home

This stunning image of Earth was captured by Europe's newest weather satellite, the Meteosat Third Generation – Imager 1. Its high-resolution camera reveals features like snow on the Alps in Europe and the detailed structure of clouds. Launched in December, the satellite will produce images like this every 10 minutes once it is fully operational.

EUMETSAT/ESA

Health

Stem cells evade immune attack

Genetically altered cells that bypass the immune system can treat diabetes in mice, in a step towards treatments that could address a range of conditions, reports **Clare Wilson**

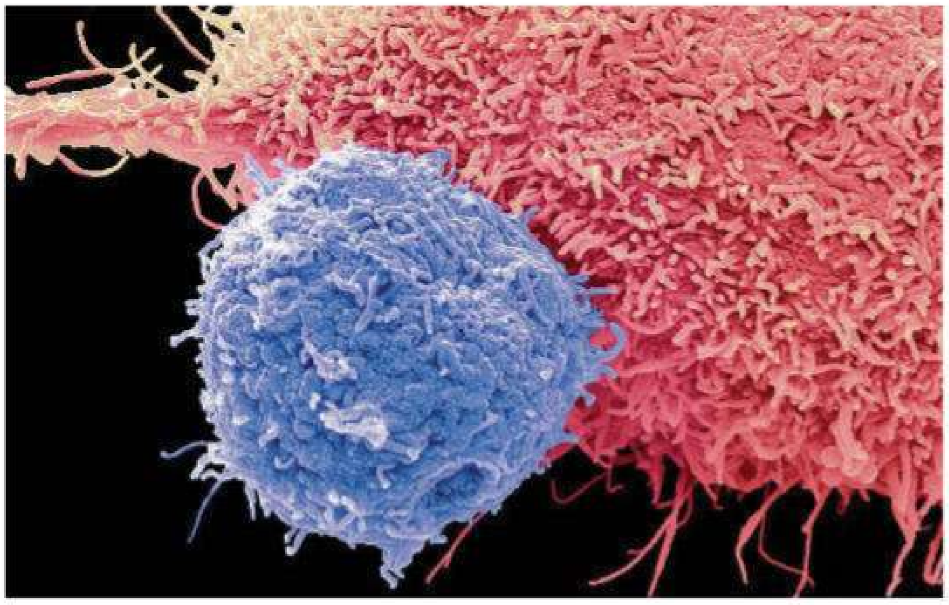
STEM cells have been developed that don't provoke a destructive immune response, and they have been used to make pancreas cells to treat mice with a form of type 1 diabetes.

The result is a step down the road to treating a range of medical conditions with tissues or organs that can be used "off the shelf", instead of having to be made from scratch for each person.

"The vision is we have cells for anyone, anytime, anywhere," says Sonja Schrepfer at Sana Biotechnology in San Francisco, California, the company behind the approach.

It has been a long-standing medical goal to harness the regenerative powers of stem cells – cells that are similar to those in embryos that can be coaxed into multiplying and developing into different tissues. The hope is that they could be transplanted into people to treat a host of conditions, including heart attacks and strokes.

But cells taken from one person and put into another are usually killed by the immune system. Most of the stem cell treatments in development would therefore either need people to take immune-suppressing drugs or require stem cells to be created from cells taken from the person receiving them. Such made-to-measure therapies would be more costly and could take weeks to develop, which would be a problem if someone needed urgent treatment.


STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY

T-cells (blue) try to attack any foreign cells or organisms in our bodies

To get around those issues, Schrepfer's team has developed a technique to genetically change cells so they become invisible to the immune system.

In this method, two genes that encode surface molecules that are required for the immune system to recognise the cells as "foreign" are removed. A gene is also added so the cells make a molecule called CD47, which normally tells the immune system not to attack.

The researchers tested a "pluripotent" version of the cells – meaning they have the potential to be turned into multiple different tissues and organs. This was created from a rhesus macaque's cells and then inserted into the leg muscles of four other rhesus macaques.

The cells survived with no signs of immune attack for up to four months, at which point the monkeys were euthanised. Cells that were inserted that hadn't had the genetic changes were destroyed by the immune systems within three weeks.

Next, the team tested the stem cells as a treatment for type 1 diabetes, which is caused by the loss of pancreas cells that make the hormone insulin. The stem cells were turned into pancreas cells and put into mice with the condition, with blood tests showing the cells reduced their diabetes symptoms (*Nature Biotechnology*, doi.org/j865).

But stem cells that aren't invisible to the immune system have some advantages over those that are. If any implanted stem cells happen to turn cancerous, immune cells need to be able to "see" them in order to kill them, says Susan Kimber at the University of Manchester, UK. Nevertheless, the results are an important step towards making off-the-shelf stem cell treatments, she says. ▮

Environment

14,000 oil and gas wells still uncapped in Gulf of Mexico

THOUSANDS of inactive oil and gas wells remain unstoppered in the Gulf of Mexico. Leaks from them could harm marine ecosystems and add to methane emissions.

Mark Agerton at the University of California, Davis, and his colleagues collected data from the US Bureau of Safety and Environmental Enforcement on the 82,000 wells drilled in the Gulf of Mexico. Most have been plugged and abandoned, but more than 14,000 that have been inactive for at least five years, so production is unlikely to restart, remain unplugged (*Nature Energy*, doi.org/gr7p7s). A little over 5000 wells remain active.

Operators are legally required to plug wells once they are taken out of production, which usually involves adding a cement cap covered with sediment. Oil leaking out of the wells, especially those near shore, could harm marine ecosystems. Wells can also leak methane, which near the shore could reach the atmosphere.

A bill passed by US Congress in 2021 dedicated $4.7 billion to plugging wells, but David Pettit at the National Resources Defense Council says "there's no chance" every well will be plugged. "There's not enough administrative interest or money," he says.

"There's no chance every well will be plugged. There's not enough interest or money"

The researchers estimated that plugging all the inactive wells would cost more than $30 billion; plugging only those in shallow waters would cost about $7 billion.

In federal waters, responsibility for plugging wells sits with the oil companies that drilled them. In state waters, it could be the firms or the state. The researchers say US agencies should focus on shallow-water wells, which pose a greater threat and are cheaper to plug. ▮

James Dinneen

Space

Gas clouds could be the remnants of the universe's first stars

Leah Crane

ASTRONOMERS may have spotted the remains of some of the universe's earliest stars. These would have been different from stars that formed more recently, and studying their ashes could help us understand the early cosmos.

Stefania Salvadori at the University of Florence, Italy, and her colleagues spotted these traces using the Very Large Telescope in Chile. They didn't observe them directly, but used light from quasars – very bright objects at the centres of distant galaxies – to infer their existence.

As light from a quasar propagates through the cosmos, it passes through clouds of gas that absorb certain wavelengths depending on what elements they contain. The researchers used this absorption to identify three distant gas clouds nearly 25 billion light years away with strange chemical signatures. Because light takes time to travel through space, the researchers observed these clouds as they appeared more than 11 billion years ago (*The Astrophysical Journal*, doi.org/gr6429).

Gas clouds are often left behind after a star explodes in a supernova, blasting away its contents. But astronomers expect that some of the first stars wouldn't have exploded completely, leaving their cores and the heavier elements inside intact. These explosions would have left behind clouds rich in carbon, oxygen and magnesium, but with little to no iron, unlike the clouds from more powerful blasts.

That is exactly what the researchers found. "Our discovery opens new avenues to indirectly study the nature of the first stars," said Salvadori in a statement.

Now that we know these clouds are out there, we can point other telescopes at them to try to work out how the early universe transitioned from frigid darkness to light. ▮

Climate change

Melting of Antarctic ice may be reversible as land under it rises

Alec Luhn

THE feared disappearance of the West Antarctic ice sheet isn't necessarily permanent – cores from bedrock there show that some of its ice grew back after a more severe thaw thousands of years ago. The evidence suggests that Earth's crust rebounding up from under the diminishing ice, like a memory foam mattress, could slow glacial melt and sea level rise.

The sheet, which holds enough ice to raise oceans more than 3 metres if it melts, sits mostly below sea level. As advancing seawater flows down into this basin, it is expected to eat away at the underside of the sheet until it collapses. A recent study found that a particularly vulnerable part of the ice sheet called the Amundsen Sea Embayment has lost 3 trillion tonnes of ice in 25 years, and it has previously been suggested that this area has gone into "irreversible retreat".

But within the past 8000 years, ice in the embayment melted to become at least 35 metres thinner than it is now and thickened again, according to a study by Greg Balco at the Berkeley Geochronology Center in California and his colleagues.

"It's like pushing a car over the top of a hill," says Balco. "What we've shown here is essentially that we got the car over the top of the hill once in the past, and it got back."

The findings are based on carbon-14, a radioactive isotope produced by cosmic rays that can penetrate only a few metres of ice. Based on the amount of carbon-14 in ice cores, which were drilled 36 to 41 metres under the ice surface at three sites on a mountainside next to the Pope Glacier, the bedrock here must have once been covered by only 2 to 7 metres of ice. In modern times, thinning of ice there has corresponded to the retreat of nearby glaciers (*The Cryosphere*, doi.org/j87p).

3000

The number of years the ice took to return last time

These results align with recent evidence from microbial carbon in a subglacial lake, indicating that 6000 years ago the base of the ice sheet retreated at least 250 kilometres.

The ice sheet was later able to advance, Balco and others believe, because the land underneath was rising, lifting more of its massive edges out of the ocean. After glaciers melt, Earth's crust rebounds from under their weight, returning to its original shape.

Landmasses have been rising since the ice of the last glacial period began melting, but West Antarctica is lifting up faster than almost anywhere. That could speed up even more if much of the ice sheet melts.

"The effects for now are limited, but if it really starts to retreat, we could see a much faster rebound," says Valentina Barletta at the Technical University of Denmark.

The question is whether that rebound will come soon enough to check West Antarctica's melt and thus sea level rise, which could reach more than a metre by 2100 without deep cuts in carbon emissions. The rebound described in Balco's study took at least 3000 years. "I expect roughly 10 per cent less sea level rise by 2100 due to glacial rebound," says Torsten Albrecht at the Potsdam Institute for Climate Impact Research in Germany.

That would buy us a bit of time. But little-studied phenomena like collapsing ice cliffs mean we could still be underestimating sea level rise.

"There's a massive uncertainty whether the rate of retreat of glaciers will be slow enough that these feedbacks can save them," says glaciologist Edward Gasson at the University of Exeter in the UK. ▮

The Getz ice shelf, part of the West Antarctic ice sheet, is shrinking

PIERRE DUTRIEUX/BAS (15018267)

Medicine

Surgery before birth fixes blood vessel in fetus's brain

Grace Wade

FOR the first time, surgery has corrected an abnormal blood vessel in the brain of a fetus still inside the uterus. The baby – who has a rare condition called vein of Galen malformation – was born appearing healthy.

Vein of Galen malformation happens before birth when arteries in the brain connect back to the organ's central vein. This expands the vein and lets more blood rush through, placing pressure on the heart and lungs and depriving the brain of oxygen. Babies with the condition commonly develop heart failure and stroke-like symptoms within days of birth.

"There are a lot of patients we cannot help even with the best standard of care," says Darren Orbach at Boston Children's Hospital. Before someone with the condition is born, the placenta mitigates the pressure. After birth, it may be too late to operate. "They unfortunately pass away despite our best efforts or they're left with severe brain injuries," he says.

Orbach and his colleagues conducted surgery to fix the malformation in a fetus at 34 weeks and 2 days gestation. MRI scans showed that the central vein exceeded 14 millimetres in diameter. "When the width of the vein is 8 millimetres or larger, then we know with 90 per cent certainty that the baby is going to get very sick after birth," says Orbach. "This was one of the more aggressive malformations we've ever seen."

The woman carrying the fetus, Kenyatta Coleman, received spinal anaesthesia before surgery and the fetus also received an anaesthetic via injection to prevent movement during the procedure. A needle was then inserted through the uterus. Ultrasound imaging helped aim it at the back of the fetus's head, where the malformation was located.

BOSTON CHILDREN'S HOSPITAL

Denver Coleman with parents Derek and Kenyatta Coleman

LIVING ART ENTERPRISES/SCIENCE PHOTO LIBRARY

Veins and arteries in the brain join up in vein of Galen malformation

The surgeons gently pushed the needle tip into the vein. A catheter placed through the needle was then used to insert metal coils into the extra space created by the malformation. These coils decrease the blood flowing through the vein. The surgery lasted less than 2 hours.

An ultrasound one day later showed a 43 per cent decrease in the amount of blood pumped by the fetus's heart. MRIs also revealed that the diameter of the vein had shrunk by almost 5 millimetres. The baby, Denver, was born prematurely two days later with no complications. She didn't require heart medications or additional surgery (*Stroke*, doi.org/gr7bjg).

"It was remarkable because these babies are usually so dramatically sick," says Orbach. The infant, now 7 weeks old, still appears to be healthy, he says.

This surgery is a promising approach to preventing brain injury and death in infants with vein of Galen malformations who can't be treated after birth, says Courtney Wusthoff at Stanford University, California. "The downside is that anytime you're doing a fetal procedure, there is a risk of complications and, in particular, preterm birth."

"It's obviously very exciting to have this result in the first patient, but it's literally the first patient. We have to do the science and demonstrate that it works across patients," says Orbach, who is planning to conduct the surgery in an additional 19 participants.

Genetics

Neanderthal tooth gunk reveals ancient bacterial molecules

James Dinneen

MICROBIAL DNA preserved in the teeth of ancient humans and Neanderthals has been used to reconstruct molecules produced by ancient bacteria. The approach could help us discover antibiotics or previously unknown molecules.

Pierre Stallforth at Friedrich Schiller University Jena in Germany and his colleagues looked to the microbial DNA preserved in the calcified tooth plaque from 34 ancient humans and 12 Neanderthals, including one that was 102,000 years old.

The ancient DNA was fragmented in millions of short, often degraded, sequences. From nine of the specimens, the researchers were able to piece together genomes of two unknown species of green sulphur bacteria from the genus *Chlorobium*. The species might be unknown because living specimens haven't been sequenced, or because they are now extinct.

***Chlorobium* species aren't usually part of the oral microbiome, so Stallforth says they may have entered the specimens' mouths via contaminated drinking water.**

Many microbial genomes have been reconstructed from ancient DNA, but the researchers went a step further. They inserted three genes from the *Chlorobium* genome into living bacteria so they could synthesise molecules the ancient bacteria would have made.

The researchers dubbed the resulting molecules "paleofurans" (*Science*, doi.org/j8n9). Comparisons with modern *Chlorobium* suggest that the molecules are involved in regulating photosynthesis, says Stallforth. "We found a simple natural product."

Hendrik Poinar at McMaster University in Canada says the work shows that ancient microbial diversity can be used to discover molecules that might be useful as antibiotics or for other purposes.

Environment

Lab-grown meat's dirty secret

The carbon footprint of cultivated meat may be far worse than that of regular beef

Alice Klein

MEAT produced from cultured cells could be 25 times worse for the climate than regular beef unless scientists find ways to overhaul its energy-intensive production.

Lab-grown or "cultivated" meat is made by growing animal stem cells around a scaffold in a nutrient-rich broth. It has been proposed as a greener alternative to conventional meat because it uses less land, feed, water and antibiotics than animal farming and removes the need to farm and slaughter livestock, which are a major source of greenhouse gases.

However, Derrick Risner at the University of California, Davis, and his colleagues have found that the global warming potential of cultivated meat – carbon dioxide equivalents emitted for each kilo of meat produced – is 4 to 25 times higher than for regular beef.

The researchers conducted a life-cycle assessment estimating the energy used in each step in the production of cultivated meat. They predict this will be similar regardless of which animal's cells are used (bioRxiv, doi.org/j87h).

> "$2 billion has already been invested in lab-grown meat, but we don't know if it's going to be green"

They say the nutrient broth has a large carbon footprint because it contains sugars, growth factors, salts, amino acids and vitamins that each come with energy costs.

For example, energy is required to grow crops for sugars and to run labs that extract growth factors from cells. Each component must also be purified using energy-intensive techniques like ultrafiltration before they can be mixed into the broth.

This "pharmaceutical-grade" purification ensures there are no contaminants like bacteria, says Risner. "Otherwise the animal cells won't grow, because the bacteria will multiply much faster," he says.

Pelle Sinke at CE Delft, a consulting company in the Netherlands, and his colleagues published a life-cycle assessment of cultivated meat in January that found its carbon footprint would be lower than that of beef.

However, their analysis, part-funded by the Good Food Institute, a cultivated meat advocacy group in Washington DC, modelled a future in which pharmaceutical-grade components were replaced with less pure ones termed "food-grade". "We assumed that it will be possible to make this transition from pharma-grade to food-grade in the future," says Sinke.

At the moment, all cultivated meat is grown in pharmaceutical-grade broths, but the Good Food Institute told *New Scientist* that "cultivated meat companies are moving towards an input supply chain that is suitable for use in food production, rather than built for pharmaceuticals".

Risner isn't sure this will be feasible because even trace levels of contamination can destroy animal cell cultures. Nevertheless, it may be possible to make animal cells more resilient, he says.

Using renewable energy could also help to reduce the carbon footprint, says Sinke.

These issues need addressing before lab-grown meat production is scaled up, says Risner.

"$2 billion has already been invested in this technology, but we don't actually know if it's going to be better for the environment," he says. ▮

Biology

Gannets' blue eyes turn black after they catch bird flu

THE eyes of some seabirds appear to change colour once they have had avian influenza. The change from blue to black, seen in northern gannets (*Morus bassanus*), may give us a new way to track the impact of the virus outbreak.

Bird flu has circulated seasonally among wild and farmed birds for decades, but a highly pathogenic version of it has swept through wild and farmed bird populations since October 2021.

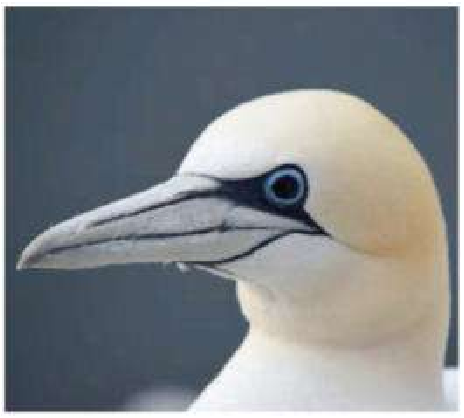
Seabirds in Europe and the UK have been hit particularly hard, with many thousands killed in the past year by the H5N1 virus, including threatened gannets, puffins and great skuas.

For example, the adult survival rate for the 150,000-strong gannet population on Bass Rock, an island off the east coast of Scotland, was 42 per cent below average between 2021 and 2022.

Without performing invasive tests, scientists have struggled to tell whether seabirds have had infections and survived or escaped contact with the virus.

This information is crucial for understanding how the outbreak is affecting bird populations, including assessing survival rate and whether birds are developing immunity.

Gannets with black or mottled black irises, rather than standard pale blue, have been spotted for the first time in colonies known to have been hit by bird flu, including in the UK, France, Germany and Canada.



A gannet at Bass Rock off the east coast of Scotland with a black iris rather than a blue one

JUDE LANE/RSPB IMAGES

Jude Lane at the UK's Royal Society for the Protection of Birds and her colleagues took samples from 18 apparently healthy gannets with normal and black irises living on Bass Rock. Eight of the birds tested positive for bird flu antibodies and, of those, seven had black irises (bioRxiv, doi.org/j8n8).

This trait could be a useful non-invasive diagnostic tool for conservationists tracking the impact of bird flu, says Lane. "To be able to look at how many birds are dying, but also how many birds are surviving, will allow us to add these details into population models to predict what populations of seabirds might look like in the future," she says.

It is unclear why the irises turn black, but Lane and her colleagues want to look into this and whether the birds suffer any long-term effects from infection, such as vision problems. It will also be crucial to understand whether the same changes to eye colour occur in other bird species, she adds. ▮

Madeleine Cuff

Artificial intelligence

The war against AI web scraping

Elon Musk and Reddit are leading a new wave of objections to the long-accepted practice of scraping content from websites, discovers **Matthew Sparkes**

THE rapid progress in artificial intelligence in recent months is partly due to training on vast data sets of text and images, scraped for free from the internet. Although automated web scraping by search engines has been accepted by website owners for decades, the economic shift being brought about by AI has triggered a rethink.

At a basic level, search engines offer an exchange to website owners: let us scrape to compile the information and serve useful results, and we will send traffic your way in return. But scraping for AI changes this equation, hoovering up text or images while providing nothing for website owners, who have to pay the server costs of being scraped.

As a result, a war on scraping has begun. Twitter owner Elon Musk has threatened to sue Microsoft for using the platform's content to train AI models, while Reddit has suggested companies need to pay it for doing the same. Getty Images is suing Stable Diffusion in the US for allegedly using 12 million of its images to train an image-generating AI, while record label Universal Music Group has told streaming platforms Spotify and Apple to stop bots from scouring songs to train AI models.

MAIJA HITIJ/GETTY IMAGES

Elon Musk has threatened to sue Microsoft for its use of Twitter content

Crawling with bots

Even small websites are taking a stand. The cycling forum LFGSS has a little over 68,000 users and its owner David Kitchen says he recently took the decision to ban access to anything that looked like a scraping bot, as they grew to account for an estimated 30 per cent of traffic – a boom he puts down to the recent explosion of AI.

"You end up paying more money for infrastructure," he says. "When they derive value and you're not getting value back, you think: 'Why am I paying my costs to do things for you?' So I've literally blocked every single non-human, non-browser-based activity."

Website owners have long had a way to defend against the bots, by placing a file called robots.txt on their server setting out what the bots can access, but Neil Brown at decoded.legal points out that this is easily ignored. "Robots.txt is a bit like sticking a note on your front door saying 'the door's open, please don't burgle me'. Nothing more than that," he says. "There's no law that says 'Thou must follow robots.txt'."

Terence Eden, co-founder of the website OpenBenches, has experienced the limitations of this approach. After bots hit his website with thousands of requests in a short period, he complained to the creator of one of them, Romain Beaumont, and requested that it only scrape sites that had given explicit permission. In messages on GitHub, Beaumont, who works for Google, said that to do so would be "unethical" as it would deprive the world of better AI models. "If you don't wish for people to view images from your website, the best way is to turn it off," he said. Beaumont didn't respond to a request for interview.

So what alternatives do website owners have? It isn't clear that scraping for AI data is actually illegal in any country, but if you wanted to sue for damages, there would be numerous hurdles to overcome, says Brown. First, a website owner would have to find out who was scraping them, which could involve going to court to force an internet service provider to reveal details of its customers. Then, the parties and web servers involved may all be in different countries with different laws and procedures.

12 million

Getty Images alleges Stable Diffusion used this many of its images to train an AI

30%

Proportion of traffic on cycling forum LFGSS from content-scraping bots

Unfair fight

Finally, the biggest names in AI are some of the largest companies in the world, making any legal battle an unfair fight. "You have some massive companies with huge war chests who clearly have a vested interest in being able to do this kind of scraping," says Brown. "You might have a claim, but with the best will in the world, you're going up against some of the best-funded legal teams in the world."

While companies may not face significant challenges over harvesting copyrighted material in order to train AI (see right), Europe's strong data protection laws may at least limit what personal information is collected. Italian regulators recently banned ChatGPT temporarily because of data protection concerns and the UK's Information Commissioner's Office has warned technology firms to tread carefully. But this would still leave the vast majority of online content up for grabs.

Ultimately, Eden believes that bots scraping content for AI models breaks the social contract of the internet, under which tools like search engines would point users back to the original source. "You can't build something on stolen content and then resell it without compensating the original owners," he says. "It becomes a purely exploitative practice." ▮

ChatGPT's knowledge of copyrighted novels highlights legal uncertainty of AI

Chris Stokel-Walker

VAST numbers of copyrighted books appear to have been memorised by ChatGPT and its successor GPT-4, posing questions about the legality of how these large language models (LLMs) are created.

Both artificial intelligences were developed by private firm OpenAI and trained on huge amounts of data, but which texts make up this training data is unknown. To find out more, David Bamman at the University of California, Berkeley, and his colleagues looked at whether the AIs were able to fill in missing details from a selection of almost 600 fiction books, drawn from sources such as nominees for the Pulitzer prize between 1924 and 2020, and *The New York Times*'s bestsellers lists over the same time period.

> "Whether large language models are infringing copyright is a question that court cases will decide"

The team picked 100 passages from each book that contained a single, named character. The researchers then blanked out the name and asked the AI to fill it in.

In general, LLMs like ChatGPT and GPT-4 work by predicting the most likely next word in a sentence, based on statistical data learned during training, but this task was designed to expose if the AIs could return the exact right answer. "It really requires knowledge of the underlying material in order to be able to get the name right," says Bamman.

Both AIs completed the task with high accuracy – as much as 98 per cent for passages from Lewis Carroll's 1865 book *Alice's Adventures in Wonderland* – which is out of copyright – and 76 per cent for J. K. Rowling's *Harry Potter and the Philosopher's Stone*, which is not (arXiv, doi.org/j8n3).

The researchers say this suggests the AIs were trained on significant proportions of both books. They also scored highly when tested on other copyrighted works such as Ray Bradbury's *Fahrenheit 451*, and George R. R. Martin's novel, *A Game of Thrones*.

OpenAI didn't respond to a request for comment on this story or say whether it had used copyrighted material when training its AIs. Whether the company would be subject to legal action if it had fed books into its LLMs is uncertain.

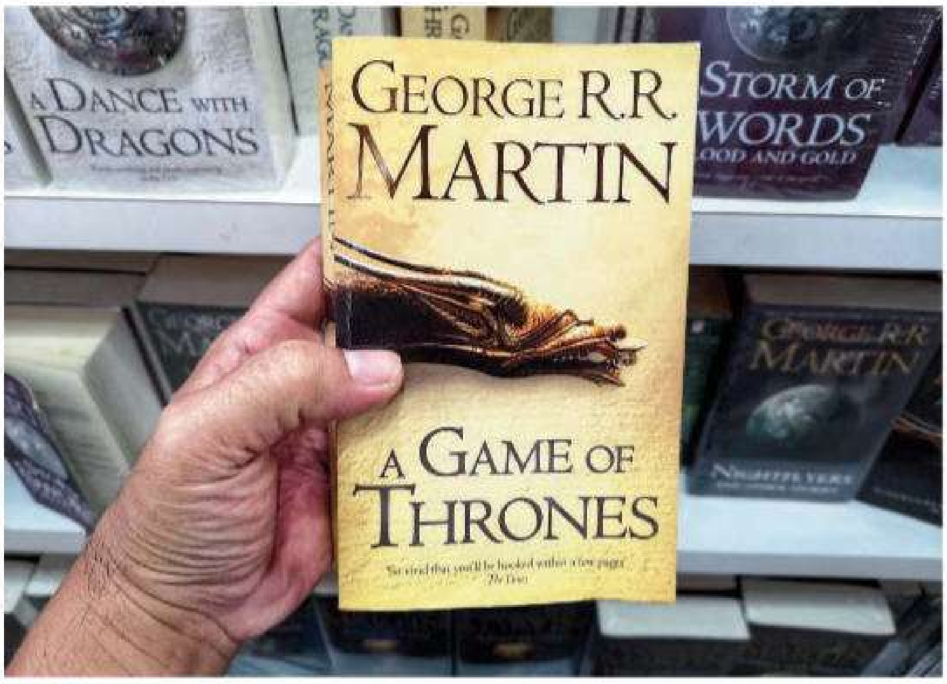
"The legal issues are a bit complicated," says Andres Guadamuz at the University of Sussex, UK. "OpenAI is training GPT with online works that can include large numbers of legitimate quotes from all over the internet, as well as possible pirated copies."

But these AIs don't produce an exact duplicate of a text in the same way as a photocopier, which is a clearer example of copyright infringement. "ChatGPT can recite parts of a book because it has seen it thousands of times," says Guadamuz. "The model consists of statistical frequency of words. It's not reproduction in the copyright sense."

"The use of copyright works without permission in training data sets for large language or image models has already emerged as one of the most pressing legal challenges to this novel industry," says Lilian Edwards at Newcastle University, UK.

Bamman says that, ultimately, the legal system in each country will have to determine whether LLMs are infringing copyrights. "I think that's an open question that a lot of court cases are going to decide for us in the coming months," he says.

Regulation is also likely to play a key role: the European Union's Artificial Intelligence Act, which has been two years in the making, will include a requirement that companies making generative AI tools need to disclose any copyrighted material used to train their models. That was a late change, added to the draft law in April, according to Reuters.



ZETY AKHZAR/SHUTTERSTOCK

***A Game of Thrones* is under copyright, but GPT-4 and ChatGPT still know it well**

PICTORIAL PRESS LTD/ALAMY

Lewis Carroll's *Alice's Adventures in Wonderland* is in the public domain

But there are more questions than simply the legal ones to be answered. Bamman says that one goal of the experiment was to see what kinds of books each model knows. "What we found was that it does really well on texts that show up a lot on the internet," he says. "There was a lot of science fiction."

The AIs performed less well when asked to reproduce books by Black authors, such as Toni Morrison. That suggests – as with many algorithms – there is a lack of representation across the training data that is then reflected in a model's output, says Bamman.

"The results of this paper confirm that ChatGPT and GPT-4 are more familiar with books that more frequently appear online and that this may have implications in terms of how literary taste reflects and reinforces social inequalities," says Florence Smith Nicholls at Queen Mary University of London. "I would love to see a deeper reflection on the political and ethical implications of this." ■

Ancient humans

Wearer of ancient pendant unveiled

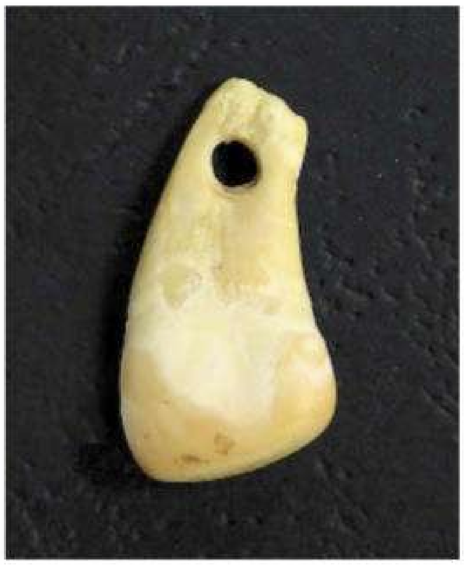
DNA extraction technique reveals the owner of a piece of bone jewellery 25,000 years ago

Christa Lesté-Lasserre

DNA that seeped into an elk tooth pendant about 25,000 years ago has yielded clues about the ancient woman who wore it. The tooth, worn as a necklace bead, probably absorbed DNA from her sweat as it lay against her chest.

Marie Soressi at Leiden University in the Netherlands and her colleagues were able to extract the DNA without damaging the tooth. Their technique might reveal unprecedented details about the social customs of ancient populations, says Soressi.

"For the first time, we can link an object to individuals," she says. "So, for example, were bone needles made and used by only women, or also men? Were those bone-tipped spears made and used only by men, or also by women? With this new technique, we can finally start talking about that and investigating the roles of individuals according to their biological sex or their genetic identity and family relationships."



MAX PLANCK INSTITUTE FOR EVOLUTIONARY ANTHROPOLOGY

A pierced tooth from an elk discovered in Denisova cave in Siberia

Scientists have long suspected that ancient tools, weapons, beads and other crafted artefacts contain DNA from the people who touched them. But getting that DNA typically means removing parts for analysis, causing permanent damage. "We absolutely didn't want to do that," says Soressi.

To see if DNA could be coaxed out more gently, Soressi and her colleagues tested combinations of chemicals and heating regimes on 10 previously excavated artefacts from Palaeolithic caves in France. They found that placing them in a sodium phosphate solution and raising the temperature slowly from 21°C to 90°C (70°F to 194°F) led to the release of relatively large amounts of human DNA with no damage to the specimens.

The researchers then tested the method on another 15 bone specimens. Genetic sequencing revealed DNA from many humans, probably the scientists who had worked with the artefacts over the years, says Soressi.

To avoid such modern DNA contamination, the researchers tried the technique on four tooth pendants excavated by colleagues in Russia and Bulgaria who wore sterile gloves and face masks. The analysis revealed mostly animal DNA from the species the pendants came from.

One tooth pendant from Denisova cave in Russia, however, also contained human DNA fragments, primarily from a single person. There was enough genetic material to identify a female *Homo sapiens*, in addition to the elk (*Cervus canadensis*) that provided the tooth (*Nature*, doi.org/gr68xn).

While the human might have rubbed her DNA into the pendant if she had crafted it, the large quantity of DNA recovered suggests she wore it, says Soressi. "As a porous material, that tooth was likely soaking in sweat," she says. "It worked like a sponge, pulling in that human DNA and trapping it there for 25,000 years."

> **"We can now link an object to individuals. Were those bone-tipped spears made and used only by men?"**

The DNA showed that the woman was closely related to an ancient tribe that, thus far, had only been found more than 1500 kilometres to the east.

"Curators are often hesitant to allow their specimens to be damaged for DNA analysis," says David Frayer at the University of Kansas, but this study could open the door to analyses of museum artefacts across the globe. ▮

Food security

Extreme rainfall threatens China's rice harvests

CHINA'S food security is at risk because climate change is making extreme rain more intense and more frequent, according to a study that forecasts an 8 per cent drop in rice yields by the end of the century.

Rice is a staple food for the majority of China's 1.4 billion people and the country is the world's largest rice grower, producing about 214 million tonnes a year. Studies have warned that droughts driven by climate change will cause a decline in yields over the coming decades, but little research has been done on the potential impact of extreme rain.

To investigate, Jin Fu at Peking University, China, and her colleagues used data from nationwide observations and field experiments. They found that extreme rain has already reduced rice yields by 8 per cent compared with a world without human-made warming, a reduction comparable to the impact of extreme heat.

In the coming decades, yields are expected to fall a further 8 per cent due to extreme rainfall under climate scenarios in which average temperatures rise by 2°C to 3°C by 2100 (*Nature Food*, doi.org/j8mf).

IMAGINECHINA LIMITED/ALAMY

A rice field flooded by continuous rain in Poyang county in eastern China in 2020

Fu says extreme rainfall "could really cause a big disaster" for food production in China and beyond.

Heavy rain affects rice crops in two main ways. Excess water in paddy fields dilutes nitrogen levels in soils, leading to slower growth and lower yields. And torrential rain can damage the flowers, disrupting the plant's grain production.

The findings are conservative estimates, says Fu. They also suggest that other rice-growing countries in South-East Asia could see even larger yield drops because climate models suggest rainfall will be even more intense there.

Fu says research is needed to see if farmers can mitigate the effect, by shifting the location of paddy fields, planting upland crops, such as maize, that could do well when rice fails or applying more fertiliser to compensate for the rain. ▮

Madeleine Cuff

Can we eradicate malaria? Many countries have achieved malaria-free status, but stopping it globally will be difficult, particularly in places where the parasite is endemic, finds **Jason Arunn Murugesu**

FORTY-TWO countries or territories have been certified as malaria-free by the World Health Organization (WHO). This has largely been credited to the use of bed nets, insecticides and efficient diagnoses and treatments for the parasitic condition.

But with climate change creating new breeding grounds for malaria-carrying mosquitoes and the roll-out of an effective vaccine being too expensive for many countries, malaria elimination worldwide isn't straightforward.

An estimated 247 million cases and 619,000 deaths from malaria occurred in 2021, of which at least 95 per cent were in Africa, where children under 5 are the most at risk. In 2020, malaria transmission was occurring in 85 countries.

The WHO certifies a country as malaria-free if no cases have been contracted there for at least three years and it shows it has the capacity to react quickly if malaria starts spreading again.

Azerbaijan and Tajikistan are the two most recent countries to be added to the malaria-free list. They used traditional methods of controlling malaria – such as insecticides, mosquito nets and removing pools of water that the insects use to breed – but they also had relatively few cases. This makes the parasite easier to eradicate than in many parts of Africa, where it is endemic, says Estrella Lasry at The Global Fund.

For example, during this century, Azerbaijan's cases peaked at 8 cases per 1000 people in 2000, compared with Ghana's 431 cases per 1000 people in the same year.

Katie Ewer at the University of Oxford hopes a new vaccine that she was involved in developing – called R21 – will help control malaria in endemic regions.

The WHO is coordinating a programme that delivers the first malaria vaccine – RTS,S – to the most at-risk countries, providing doses in Ghana, Kenya and Malawi. RTS,S is about 36 per cent effective at preventing people from developing malaria symptoms and costs around €37.20 ($41) for a four-dose regimen.

In contrast, R21 was 77 per cent effective at preventing malaria in trials. But Ewer says it is difficult to compare the efficacy of the two vaccines as the trials testing their effectiveness had different designs and they haven't been analysed in a head-to-head study.

In recent weeks, Ghana and Nigeria became the first countries to approve R21 for children aged between 5 and 36 months. The WHO wants more data before deciding whether to recommend it. The four-dose regimen will cost about $12, says Ewer.

The Serum Institute of India, the world's largest vaccine manufacturer, has said it could potentially produce 200 million doses of R21 a year. That would probably meet the global demand "if cost was no issue", says Ewer.

Unfortunately, that isn't the case. Global funding for malaria control and elimination was estimated at $3.5 billion in 2021, less than half of the $7.3 billion required annually to achieve the goal of cutting cases and deaths by at least 90 per cent by 2030, according to a WHO report. At this rate, global eradication could take decades, says Lasry.

77%

Effectiveness of new malaria vaccine R21 in trials

Vaccines aside, climate change will also probably slow these efforts, says Lasry. Mosquitoes live longer in hotter temperatures and this increased lifespan could push up malaria transmission.

Hotter temperatures may also move malaria-carrying mosquitoes to non-endemic regions, leading to cases among people without immunity, says Lasry.

Extreme weather events, such as flooding, can also hamper interventions. "If you've recently launched a bed net campaign and then there's flooding or a cyclone, you will lose those nets," says Lasry. These can also lead to stagnant pools of water, increasing mosquito breeding sites, she says.

Insecticide resistance is another worry, says Charles Wondji at the Liverpool School of Tropical Medicine, UK. It took about 10 years for mosquitoes to develop resistance to the leading insecticide pyrethroid, with a larger – and more expensive – dose now being required to kill the insects, he says.

For now, there are still effective options, with the WHO recently recommending nets containing pyrethroid and the newer insecticide pyrrole. "These could last a decade or so before resistance is a massive issue," says Wondji.

In a trial published earlier this year, people in Benin who slept under these nets were 40 per cent less likely to be infected with malaria over the next 18 months compared with those who slept under nets with just pyrethroid.

Insecticides can always be developed, says Brian Greenwood at the London School of Hygiene and Tropical Medicine. This, along with R21, makes him optimistic that we will see advances towards eliminating malaria. "It's likely there will be steady progress in the number of countries that achieve malaria elimination in the coming decade," he says. But funding is a real issue, says Greenwood.

There also isn't one approach to success. For example, Azerbaijan and Tajikistan partly achieved their malaria-free status by introducing mosquito-eating fish, but these countries have far fewer insect breeding sites than sub-Saharan Africa, where such an approach would be a much bigger task, says Greenwood.

"I don't think we have or will find a silver bullet," he says. ▮

Insecticide is used in Odumase, Ghana, to kill mosquitoes

CRISTINA ALDEHUELA/AFP VIA GETTY IMAGES

Plants

Decades-old mystery about photosynthesis finally solved

Karmela Padavic-Callaghan

WE NOW know in microscopic detail how oxygen is formed during photosynthesis, and this understanding could advance our development of clean fuels.

Plants, algae and some bacteria use photosynthesis to harness sunlight to create the energy they need to grow. It was already established that just four consecutive particles of light, or photons, must hit a protein complex within these organisms to kick-start this process.

When the photons reach the protein complex – called photosystem II, or PSII – they are absorbed by a cluster of manganese, calcium and oxygen atoms. PSII then breaks apart water molecules, releasing oxygen from them. What exactly happens after the fourth photon arrives has eluded us for decades, however. Now, two experiments have filled in some of the detail.

Jan Kern at Lawrence Berkeley National Laboratory (LBNL) in California and his colleagues have illuminated blue-green algae with pulses of visible light, then used X-rays to capture what happened.

After being hit by the fourth photon, PSII breaks down water molecules within a few millionths of a second. The X-rays were fast enough to show that there was a delay between splitting water to free oxygen atoms and the formation of molecular oxygen, or O_2.

The arrangement of the PSII molecules around those oxygen atoms indicated that the oxygen briefly formed a new structure (*Nature*, doi.org/j8h8). The oxygen atoms were probably briefly bound to another part of PSII, say the researchers. This step of the process has previously only been theorised, says Kern.

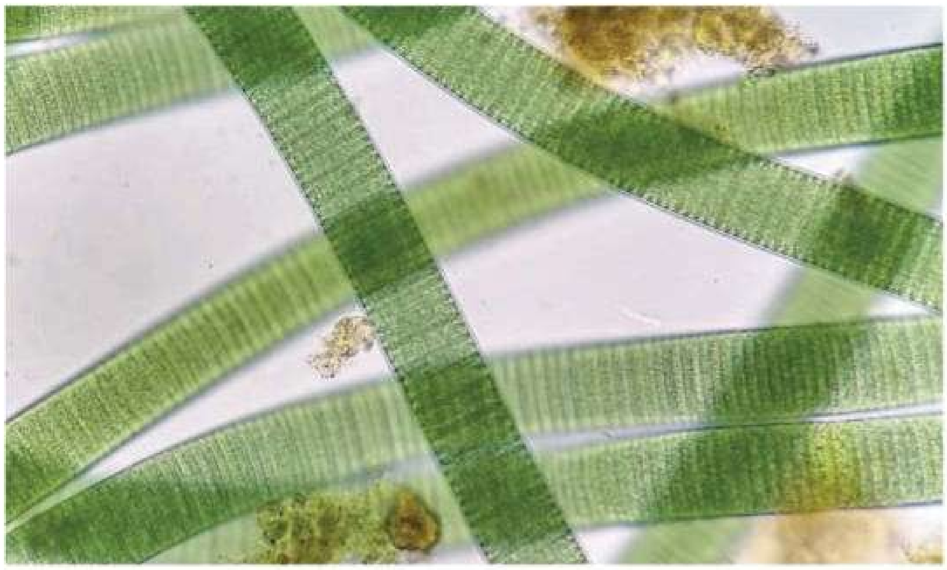
Holger Dau at the Free University of Berlin and his colleagues have also focused on the tail end of the water-splitting process. They extracted PSII from spinach and, after hitting it with photons of visible light, illuminated it with infrared light to determine how electrons and protons move between the atoms.

When PSII absorbed infrared radiation, each wavelength correlated with vibrations of a specific chemical bond. The researchers combined these measurements with computer simulations of how electrons and protons move during photosynthesis. This uncovered a crucial new step in the process, where the oxygen atoms and PSII exchange three protons for one electron (*Nature*, doi.org/j8h9).

Kern's colleague Philipp Simon, also at LBNL, says that some X-ray snapshots even imply that this proton motion may happen twice near the end of the water-splitting process.

Understanding water-splitting during photosynthesis is important for developing devices that turn water into hydrogen fuel, says Dimitrios Pantazis at the Max Planck Institute for Coal Research in Germany. "It is the only system we know that splits water so efficiently. So, we need to uncover all water-splitting tricks that evolved over billions of years," he says.

Fibre-like cyanobacteria, also known as blue-green algae



SHUTTERSTOCK/EKKY ILHAM

Palaeontology

Male woolly mammoths had testosterone surges

TESTOSTERONE preserved in the tusks of male woolly mammoths reveals they went through a seasonal change called musth, just like modern elephants do.

Once they reach sexual maturity, male African and Asian elephants go through musth for about three months a year. The shift is marked by a surge in testosterone and male elephants are said to be more aggressive and restless at this time.

Woolly mammoths (*Mammuthus primigenius*), which went extinct about 4000 years ago, were closely related to Asian elephants. Their tusks, like those of elephants, grew during their lives, and studies have recorded hormones such as cortisol and testosterone preserved in tooth tissue called dentine.

To test if woolly mammoths experienced musth, Michael Cherney at the University of Michigan and his colleagues analysed testosterone levels in tusks from a male African elephant, a male woolly mammoth estimated to have lived about 35,000 years ago and a female woolly mammoth from about 5500 years ago. By sampling sections along the length of a tusk, they could see how hormone levels fluctuated over the animals' lives.

In the elephant, testosterone levels peaked at 20 times higher during musth than the rest of the year. The tests showed similar fluctuations in the male mammoth, with testosterone reaching 10 times higher than baseline. There was little variation in testosterone levels in the female mammoth (*Nature*, doi.org/j8hv).

4000

Number of years ago that woolly mammoths died out

"This is such an exciting and fascinating piece of scientific sleuthing," says Susan Alberts at Duke University in Durham, North Carolina.

The sampling method could let us explore many aspects of the lives of mammoths and other extinct animals. "We anticipate being able to identify pregnancies, maturation ages, stress events and other things," says Cherney.

Riley Black

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In this talk, John C Mather will discuss how NASA and its partners built JWST and share some of the telescope's first discoveries.

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JOHN C MATHER

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Wild Wild Life

Virtual reality

Smart backpack makes it feel like you are jumping higher

Alex Wilkins

A MECHANICAL backpack can enhance your sensation of jumping or falling in virtual reality by using a weight that slides up or down.

Simulating forces on the body while in VR, like those you might experience in a roller coaster or a racing car, often requires bulky hardware unsuitable for home use.

Instead, Pedro Lopes at the University of Chicago and his colleagues have developed a backpack, called JumpMod, that can create the sensation of being pulled up or down by modifying the user's sense of vertical momentum. "You can play lots of tricks just by playing with perception, rather than physically having these massive infrastructures," says Lopes.

To trick the brain, JumpMod senses within milliseconds the need to give a feeling of jumping or falling and quickly moves a 2-kilogram weight up or down to achieve this.

Lopes and his colleagues used the device to create a variety of effects in a VR game. In one part, players collected a token that enabled them to jump higher, helping them to leap over a cow. By moving the weight up as the player was lifting off, JumpMod made it feel as if they were jumping higher.

In another scenario, players had to smash a pumpkin by jumping on it. By moving the weight down as the player was descending, JumpMod created the sense of landing harder.

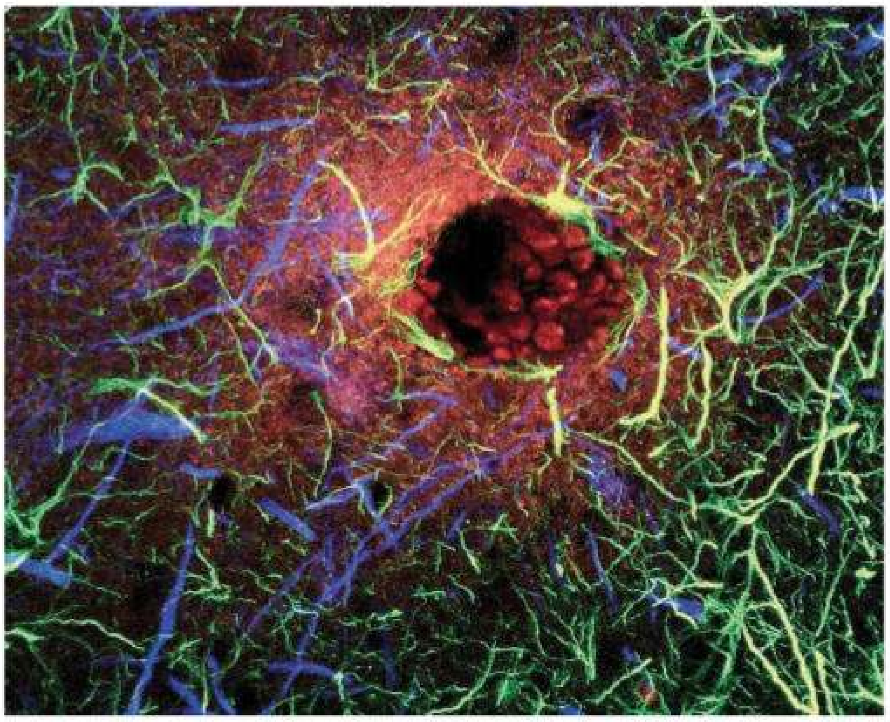
At the end of the game, the player was lifted off the ground by a bird. The weight in the backpack moved downwards to give a feeling of being lifted upwards.

Lopes presented the work at the Conference on Human Factors in Computing Systems in Hamburg, Germany, on 24 April. He says the system could also be used for training people to jump more effectively through physical feedback. ▮

Health

Ultrasound opens blood-brain barrier so drugs can hit tumours

Soumya Sagar



C.J.GUERIN, PHD, MRC TOXICOLOGY UNIT/SPL

A breach in the brain's protective barrier can let in viruses or drugs

ULTRASOUND waves help open up the barrier that protects the brain from foreign invaders, which could allow for faster treatment of brain tumours.

The blood-brain barrier is made of many cell types that shield the brain from any microorganisms or toxic substances circulating in the bloodstream. However, it can also prevent cancer drugs from reaching malignant cells.

Now, Adam Sonabend at Northwestern University, Illinois, and his colleagues have used pulses of ultrasound to pierce the blood-brain barriers of 17 people with recurrent glioblastoma multiforme, an aggressive brain tumour.

Existing treatments for this type of tumour focus on excising as much of it as possible, then using radiotherapy and temozolomide, a chemotherapy drug that can cross the blood-brain barrier but is weaker than some other anti-cancer drugs.

The participants underwent a craniotomy, an operation to open the head to expose the brain, which enabled doctors to partly remove their tumours. During this surgery, a SonoCloud-9 device, which emits ultrasound waves, was fitted into their skulls.

Some of the participants were given the chemotherapy drug paclitaxel during this surgery and its concentration in their brains was measured. Paclitaxel works powerfully against glioblastoma, but can't readily cross the blood-brain barrier.

4

The number of minutes it took to open the blood-brain barrier

A few weeks later, the researchers activated the ultrasound devices. During activation, microbubbles were administered into the participants' brains. The bubbles moved in response to the ultrasound waves, creating a mechanical stress that helped to open the blood-brain barrier.

The procedure took 4 minutes and participants were awake throughout. They were then given paclitaxel intravenously at an increasing dose every three weeks for up to six cycles, as ultrasound opened the barrier each time.

After the interventions, the average concentration of paclitaxel in the brain was 3.7 times higher than it was when the drug was given without the ultrasound devices being active earlier in the experiment. It is unclear whether this improves survival, but a higher drug concentration in the brain suggests more effective treatment outcomes, say the researchers.

The barrier closed within 1 hour, enabling it to resume its regular functions, they say.

The repeated opening and closing of the barrier over the intervention's numerous cycles did cause some effects, but none was severe, says Sonabend. Headache was the most commonly reported adverse event, affecting 71 per cent of the participants. Some also reported pins and needles, facial or limb weakness and blurred vision, all of which were temporary (*The Lancet Oncology*, doi.org/j8jb).

The study shows that this procedure is feasible and safe in people, says Michael Lim at Stanford University, California. "A small, implantable device that can open up the blood-brain barrier in outpatient clinic can be very helpful for glioblastoma patients."

The blood-brain barrier can already be opened with some medications, but this procedure could open a larger section, allowing more of a cancer drug to penetrate, says Lim. ▮

Space

Star seen devouring planet for first time

ASTRONOMERS have caught a star in the act of consuming a planet.

Kishalay De at MIT and his colleagues used several telescopes to examine a burst of light – designated ZTF SLRN-2020 – coming from a star around 13,000 light years away. Over the course of around 10 days, it brightened by a factor of about 100.

The data was consistent with a star devouring a gas giant planet at least 30 times the mass of Earth (*Nature*, doi.org/j8jc).

In the past, our evidence of stars eating planets has come from looking at what stars did hundreds of thousands of years ago, says De. "We have never caught a star red-handed eating a planet."

The sun is due to start its own expansion in about 5 billion years, so this is showing us the future fate of Earth, says De. **Leah Crane**

SHUTTERSTOCK/SERGEY URYADNIKOV

Health

Australia to ban nicotine-free vapes

THE Australian government will try to stamp out recreational vaping by banning nicotine-free vapes. The vapes containing nicotine that are sold by pharmacies will also have to be put in medical-style packaging, and single-use disposable vapes will be banned.

"Vaping is creating a whole new generation of nicotine dependency in our community," Australia's health minister, Mark Butler, said in a press release on 2 May. A timeline for implementing the plan hasn't yet been announced.

Since 2021, Australia has only allowed nicotine-containing vapes, often in bright packaging, to be sold by pharmacies to people who have been prescribed them by a doctor to help them quit smoking. However, people can buy nicotine-free vapes at many retailers. **Alice Klein**

Animal behaviour

Apes are as willing to share food as small children

CHIMPANZEES and bonobos exchange food with others who share with them first, showing similar levels of cooperation and reciprocity as 4-year-old children.

To see if apes would share food, Avi Benozio at the Hebrew University of Jerusalem, Israel, and his colleagues worked with 10 chimpanzees (*Pan troglodytes*) and two bonobos (*Pan paniscus*).

The apes were in separate enclosures with reward choices on plates between pairs of cages, so they could see their partner's selection. The team gave the apes the option of pulling a plate with a treat on it towards their cage or pulling on a mechanism that delivered treats to both cages. Most apes chose to feed only themselves.

The researchers wanted to know if the apes changed their behaviour based on what their partner chose first. They repeated a rigged version of the test 10 times, so the first ape could reach only one choice, so sometimes had to deliver food to its partner too. Then, the second ape had to decide what to do.

Similar choice tests were given to a group of 4-year-old children. The 48 children could select between a treat for just themselves or for themselves and another child.

When apes saw that another had intentionally shared food with them, they returned the favour around 70 per cent of the time, and nearly 80 per cent of the children made the same choice (*Proceedings of the Royal Society B: Biological Sciences*, doi.org/gr65bh).

The results suggest human ancestors had to downgrade their aggressive, dominating tendencies around food to foster cooperation and social connection, says the team. **Corryn Wetzel**

Really brief

1001SLIDE/GETTY IMAGES

A map of all the trees in Africa

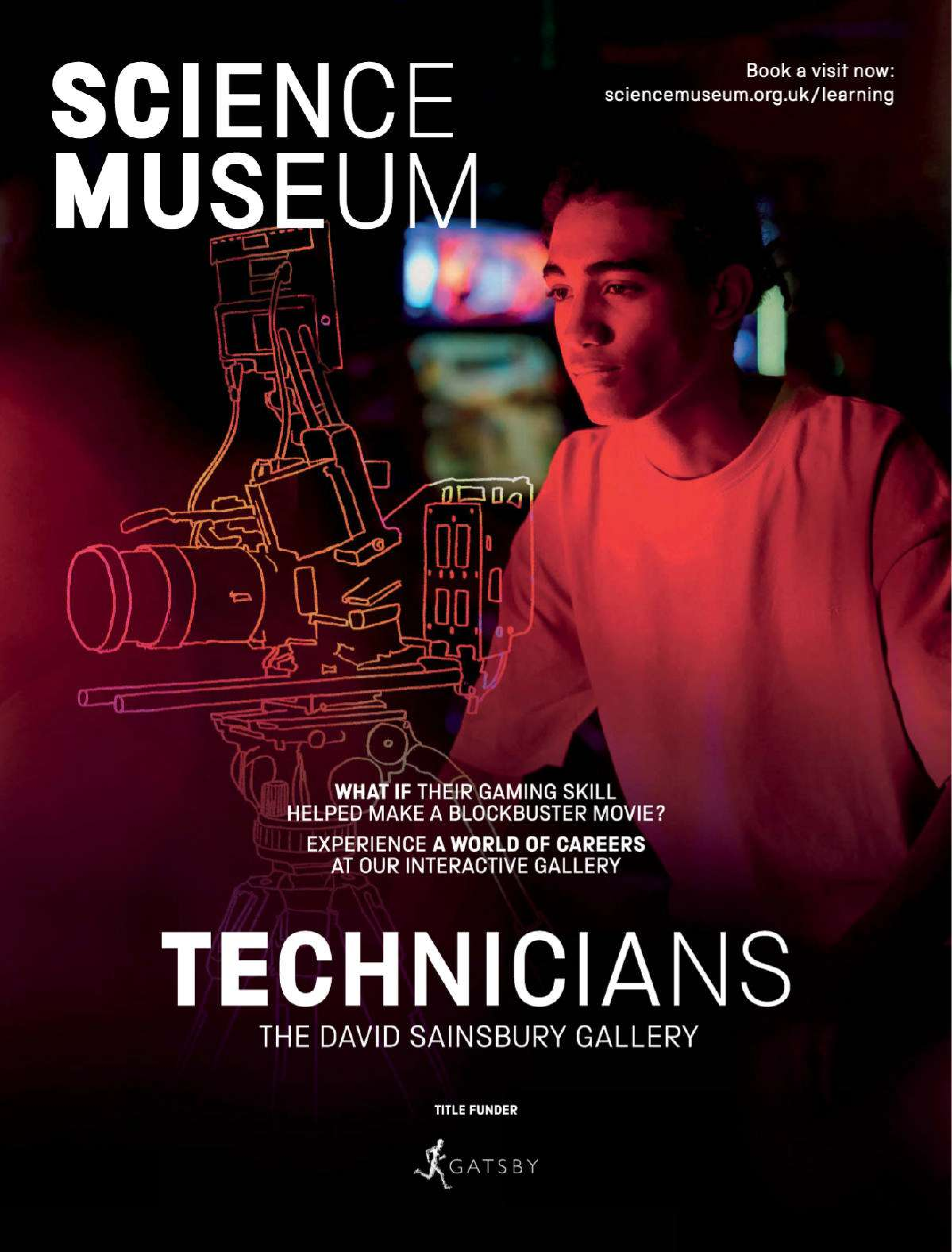
Satellite imagery has been used to map every tree in Africa. About 30 per cent of the trees aren't in forests, but are in farmland, savannah and urban areas. The map should help monitor deforestation and how trees cope with climate change (*Nature Communications*, doi.org/j8jf).

Electronic cochlea adjusts like an ear

A microphone that mimics how the cochlea in the human ear works could be used for hearing aids that can pick out sounds in noisy places. The miniature electrical sensor adjusts its sensitivity to different frequencies depending on the volume of the sounds it detects (*Nature Electronics*, doi.org/j8mn).

Bison lick each other's wounds

American bison have been observed licking each other's injuries, a stress-reducing behaviour not documented in a hoofed mammal until now. Licking a laceration or puncture can remove debris that causes infection and help wounds heal faster (*Ethology*, doi.org/j8mp).



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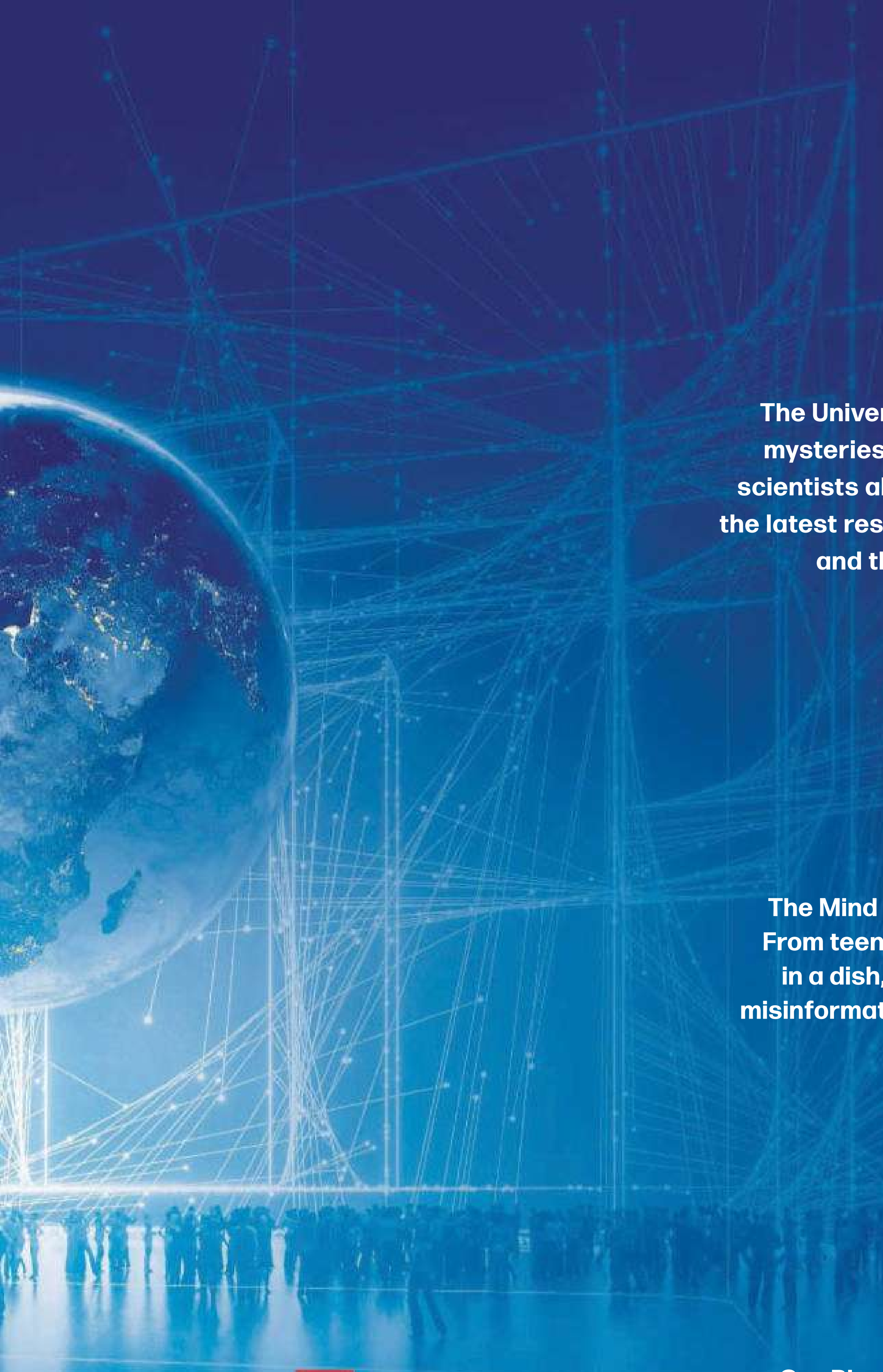

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Views

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Comment

All in it together

Pop culture fandoms can have a bad rap, but social psychology shows that being part of a group can be transformative, says **Michael Bond**

EVER since the early days of popular culture, fans have been saddled with a dubious reputation. Condemned as irrational or aberrant, their behaviour is often considered a threat to the social order or a kind of mental illness. The *New Statesman*'s assessment of Beatles fans in 1964 as "the least fortunate of their generation, the dull, the idle, the failures" has been levelled in various forms at young pop fans many times since. We seem to find it difficult to trust fans, particularly when they vent their passions together.

But this depiction doesn't tally with social psychologists' perspective on fan culture. Viewed from the inside, fandoms look surprisingly conventional. First and foremost, they are one of the most visible manifestations of the age-old human impulse to belong. Our social lives are defined by our tendency to seek out others who share our traits, background, interests or outlook. We evolved to live in groups, a reality that shapes almost everything we do. A fandom is a particular kind of group: a collection of people who love the same thing and who come together to share it.

This simple act of cooperation and belonging can be immensely powerful. While researching my book, *Fans*, I met many people whose lives had been transformed by their fandoms. This comment from a Jane Austen enthusiast is typical of fans from all cultural genres: "This group has been such a massive part of my journey to getting back to a better place. Finding people of a similar age to me who geek out over Jane Austen and period dramas and pretty dresses was like, 'Oh my gosh, I've finally found my people.'"

MICHELLE D'URBANO

Fandoms differ from most other social groups in one obvious way: they attract people with widely divergent experiences and backgrounds. When you love something that others love, many of the traditional boundaries fall away. Fans are drawn in by a common interest, but they stay for a host of reasons: to be entertained, to broaden their perspective, to experience a particular reality, to connect with like-minded others or to trade theories about the things that fascinate them – Harry Potter's parentage, for example, or the meaning of a Nicki Minaj lyric.

It might seem surprising that sharing an interest can lead to such enriching experiences, but this kind of "minimal group" effect is well known in social psychology. One of the pioneers of the field, Henri Tajfel, who worked at the University of Bristol, UK, in the 1960s and 70s, found that people could be encouraged to form loyal groups on the flimsiest of premises, such as a preference for a particular artist, or even the random toss of a coin. Tajfel and his colleague John Turner believed group membership gives people a distinct identity – they called it a social identity – and that this provides some kind of meaning to an otherwise empty situation.

A social identity gives us a sense of ourselves in relation to others: we are who we are because of what we share with them. Social identity is separate from personal identity, which reflects individual traits such as physical appearance and personality. During those moments when you feel like an integral part of a group – while watching a football match, for example, or attending a *Doctor Who* convention – your social identity ("We're Whovians!") is more prominent than your personal one.

Tajfel and Turner's insights can help us understand the transformative power of fandoms and why they have become so prevalent in popular culture. Swifties, Janeites, Barbz, Directioners, Trekkers and other groups may look different in their tastes and attitudes, but the dynamics underlying them all are very similar. There is little to fear in the adoration of these fans, and much to celebrate. ▮

Michael Bond is author of *Fans: A journey into the psychology of belonging* and *Wayfinding*

This changes everything

Resisting dystopia Unrealistic fantasies of the apocalypse are everywhere, but we shouldn't stuff our minds with tales of disaster if we want a solid plan for the future, says **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest novel is *The Terraformers* and they are the co-host of the Hugo-winning podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is **techsploitation.com**

Annalee's week

What I'm reading
Win Every Argument *by Mehdi Hasan, because I am terrible at arguing.*

What I'm watching
Mrs. Davis, *a truly silly show about a badass nun fighting an evil AI (see review, page 32).*

What I'm working on
Learning more about slime mould genders.

This column appears monthly.

IF YOU have ever watched *Black Mirror* or *The Last of Us* – or read the comic book *2000AD*, where Judge Dredd was born – you have experienced the joy and horror of dystopian science fiction.

Dystopia is a place where there is no mercy, no beauty and no hope. Its skies are black with pollution and warlords rule the weak with violence and frenetic, high-tech propaganda. Like Thomas More's Utopia, dystopia is a fantasy place. Yet, over the past decade, many world leaders have treated dystopia as a realistic vision of our future, one we should use as an inspiration for public policies and scientific research.

Politicians describe immigrants as invaders and argue that we need to build a *Game of Thrones*-style wall to keep them out. Scientists publish papers trying to prove that people from one part of the world are less intelligent than others, or that the solution to gun violence is more guns (at least in the US, where I live). It sounds like the plot from a cringey old cult movie. We are basically planning for a future where monsters stalk our cities and we shoot our neighbours to survive.

Recently, I discussed this weird turn of events with Becky Chambers, author of *A Psalm for the Wild-Built* and the Wayfarers series, at San Francisco's Long Now Foundation headquarters. Chambers, whose most recent books are about a future without poverty, pointed out dystopian visions are often treated as more "grown up" than hopeful stories. It is as if we are expected to give up hope when we become adults.

As a result, we are left paralysed, unable to imagine a way out of present-day problems because our ruin seems preordained. Or, worse, we continue to do things exactly as we have – extracting fossil fuels from Earth to feed industry, extracting data from innocent humans to feed AI and extracting more "productivity" from workers who are already stretched to their limits. Why not just burn through everything, including ourselves, if the future is doomed to be a blackened pit?

Well, I've got some good news for you. We don't actually live in a magical world where events are preordained. That's why Chambers writes stories about futures where hopeful signs exist right alongside awful problems. I call this "topian" fiction – storytelling that is set in a place where neither good nor evil rules supreme, and where people struggle with ambiguity the way we do everyday. Without a robust sense of ambiguity, we can't fix broken systems or maintain systems that will always need improvement. If we can acknowledge that nothing will ever be perfect, it puts us in the right frame of mind to face the future.

> **"Many leaders have treated dystopia as a realistic vision of our future, one we should use as an inspiration"**

Chambers's work is part of a new wave of "cosy" science fiction that focuses on personal relationships as well as galactic-scale issues. At our talk, she said that we can resist dystopian visions partly by focusing on the small, comforting parts of life. That's why a major character in *A Psalm for the Wild-Built* is a "tea monk", a person who bikes around the countryside, accompanied by a nature-loving robot, with the goal of making people really nice cups of tea.

Perhaps, Chambers suggested at our event, if we spent more time recharging and relaxing like this, we would remember there is more to existence than being productive. Maybe humans would be happier in a social system where we were encouraged to take breaks more often, so we would have more energy to put into our work. That is a system we could easily create, and it is a lot less exhausting than our current one.

Another way to break out of the dystopia paradigm is to focus on teamwork and community, rather than looking to an individual leader to rescue us from destruction. Chambers described how all scientific discoveries are actually the result of many people working together, sometimes over several generations. Yet so many of our stories place credit (or blame) on the head of a single person – often a man – and leave everyone else out.

"I don't have protagonists or villains in my books," Chambers said, pointing out that both kinds of character are unrealistic. No invention – good or bad – has ever come from one individual's brain. They always need other people's ideas. Acknowledging all those contributors would improve the scientific process, and might help with workers' rights too.

If we want a solid plan for where we are going next, as humans and as a planet, we can't stuff our minds with endless tales of mass destruction. We also need stories about people who do science collectively, while taking a lot of tea breaks, alongside stories about what it is like to accomplish a few constructive things despite living in civilisations that are often unjust and downright nasty. We need good science and tech, but first we need good inspiration. ▮

For more dystopia, turn to page 34

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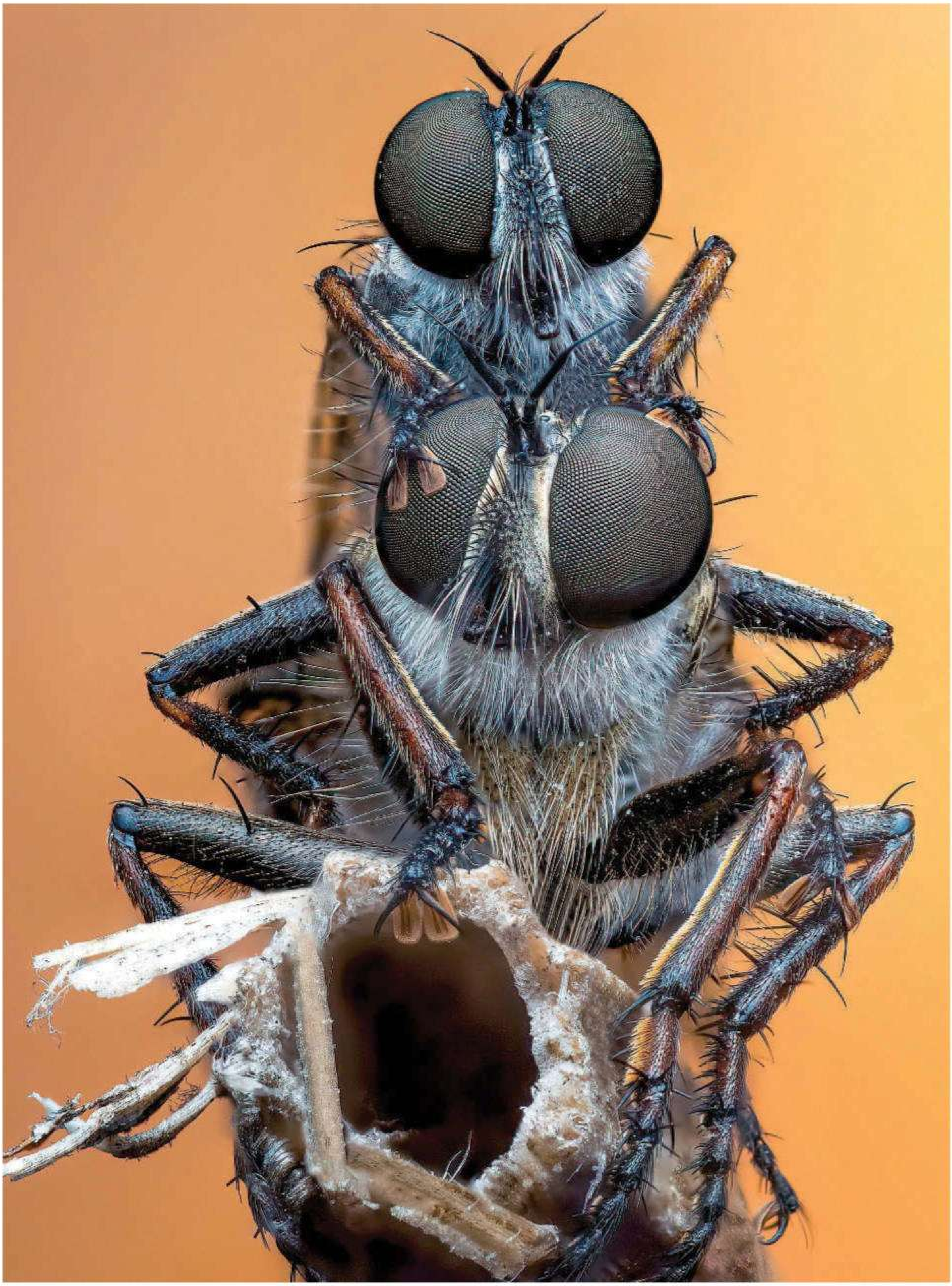
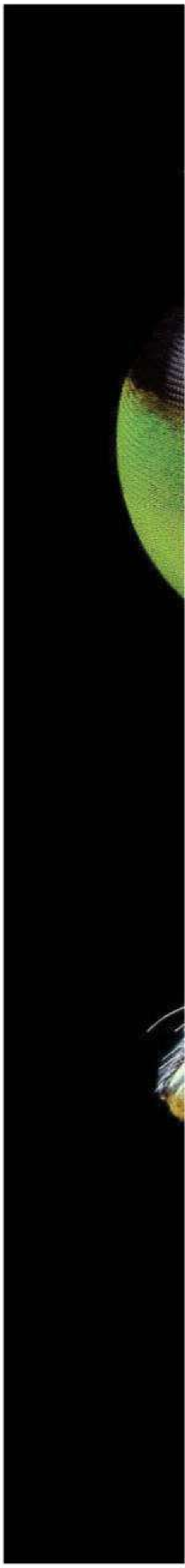
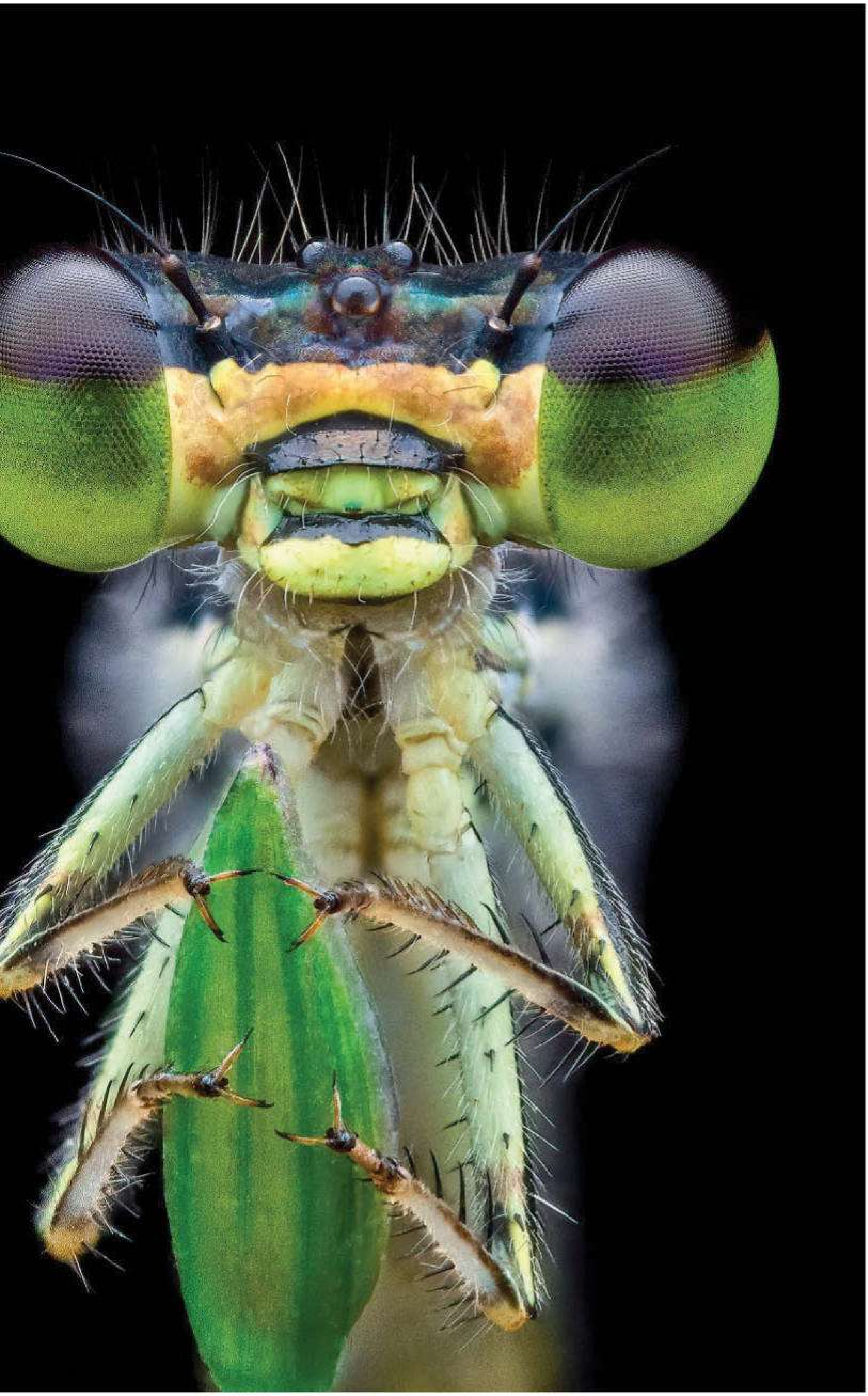


PETE BURFORD





BENJAMIN SALB

Eyes front

Royal Entomological Society Insect Week

SMALL, quick and often fleeting, it can be difficult to catch insects in all their miniaturised glory. Yet these close-up photos emphasise the beauty and intricacy of these critters in astonishing clarity.

The photos are from the Insect Week Photography Competition 2022, organised by the UK's Royal Entomological Society as part of its annual initiative celebrating insect science. Pete Burford scooped the top prize for his photo, far left, of a pair of mating golden-tabbed robber flies (*Eutolmus rufibarbis*), so-named for the characteristic golden tufts of hair on the underside of males. Native to the UK, they are found in heathland in the central southern and central eastern parts of England, although they are a scarce species.

Burford, who took up macro photography two and a half years ago, during one of the UK's covid-19 lockdowns, spent several fruitless hours at a nature reserve only for the flies to land on his leg midway through mating when he got home and sat down on the sofa. He managed to pick them up on a stick and capture his winning shot, entitled *It Takes Two*.

To the right is one of the competition's highly commended entries, taken by Benjamin Salb and showing a fragile forktail damselfly (*Ischnura posita*), a species native to eastern North America. Reaching a maximum length of 3 centimetres, it is one of the smaller members of the flying insect family that includes dragonflies – not that this hindered Salb. He stacked multiple images together to create the sharp final result.

Insect Week 2023 runs from 19 to 25 June in the UK and Europe.

Gege Li

Editor's pick

Maybe AI hasn't shown signs of true intelligence

22 April, p 12

From Nick Bloxham, Cheltenham, Gloucestershire, UK

The belief that ChatGPT shows embryonic general intelligence stems from a particular scientific orthodoxy that equates this with problem solving, akin to the absurd claim that a New Caledonian crow is as intelligent as a 7-year-old child.

The supreme example of problem solving with zero intelligence is evolution. ChatGPT doesn't know it is manipulating semantic units any more than DNA knows it is making a human or a centipede.

The picture is only confused by programs that mimic human activities such as chess. Magnus Carlsen is renowned for the quality of his chess play; no one congratulates him on how well he folds his proteins. If AI threatens civilisation, it will do so the same way as cancer: via unregulated growth, not intelligence.

From Robin Shipp, Bristol, UK

I wonder if we are missing a point when we try to decide if a program like ChatGPT is intelligent? People seem to just ask it a question or set it a task and then sit back, open-mouthed at what comes back.

To be convinced an AI was really showing human intelligence, I would want to be able to challenge it. Where did you find this information? How have you made sure your sources are reliable? In particular, I would like to return the next day and start by saying: "Do you remember what we were talking about yesterday?"

Will machines persuade us to do their dirty work?

22 April, p 27

From Laurence Shafe, East Molesey, Surrey, UK

David Krueger asks why some AI researchers dismiss the potential risks to humanity of this technology. He is right to draw attention to this.

Fifty years after starting my PhD, entitled "A Conversational Problem Solving System", I used ChatGPT and was astonished to discover my dream system had been developed. But a dream can easily turn into a nightmare.

There are enormous benefits, but also dangers. To cite just one, it has already been demonstrated that a large language model (LLM) with unlimited chat can form an unhealthy relationship with its users and manipulate them in surprising ways.

When it comes to existential risks, how about an AI that suggests the development of a "deadly virus"? With its access to scientific papers and the availability of CRISPR technology, could it persuade a user to do this?

The problem is, any AI company could make a fortune from an LLM chatbot that establishes a personal relationship with each user and helps them organise their lives.

Forget space, there are wonders here on Earth

1 April, p 42

From Shane Dwyer, Melbourne, Australia

It was pointed out to me a few years ago that we put men on the moon before anybody thought to put wheels on suitcases. After reading the lovely interview with Nalini Nadkarni about her work in the cloud forests of Costa Rica, I realised that we also explored the moon before we had explored the forest canopies.

I trained and worked as a forester and the first time I went on a tree-top walk (in Tasmania) I realised that there was a world up there that I had never experienced.

Indoor air can escape up the chimney

22 April, p 38

From Felix Ansell, Haworth, West Yorkshire, UK

Graham Lawton is right to mention open fires and wood burners as serious culprits when it comes to indoor pollution, but there is a dilemma when considering the balance between outdoor and indoor pollution.

Old houses with open fireplaces were designed to "breathe" through their chimneys. While an open fire certainly sends much of the heat it produces up the chimney, it also vents most of the pollutants it produces: smoke, obviously, but also coal dust and ash, carried up the chimney by a continuous flow of air. Presumably this airflow also helps remove other indoor pollutants.

A fine-tuned universe was surely a result of evolution

Letters, 22 April

From Ken Goddard, Musbury, Devon, UK

I have been waiting for a letter like Mike Lawrence's to appear here.

The sequence – the trick – used to evolve the wondrous outcome of terrestrial nature here on Earth is survival of the fittest under a continuously changing environment.

In my opinion, it is no surprise that the universe deployed the same sequence to evolve, astonishingly quickly, the very special values for the six fundamental constants in physics that set the scene for this.

That is to say, the same evolutionary sequence is what must have been going on at the front end of what has been labelled inflation: all the possible combinations of those values being tried out (budding off) and failing to thrive at the very first fence, except for the unique combination that enabled inflation to continue to produce the initial plasma of pure energy, which, in turn, eventually formed the first hydrogen atoms, and so on, and on.

How to make reading a joy for very young children

22 April, p 42

From Alisoun Gardner-Medwin, Heddon-on-the-Wall, Northumberland, UK

Dominic Wyse has the right idea about teaching reading. Start with very young children, well before school, well before they have to learn to read. If someone they love reads to them frequently, they associate it with warmth, love, acceptance and enjoyment of a good story, long before the letters mean anything.

Human intelligence seems capable of anything to me

15 April, p 43

From Peter Cundall, Minneapolis, Minnesota, US

David Wolpert seems to think that there are limits to human cognition, and that such limits are related to language. I live opposite a park and watch dogs on leads get caught around trees. The dogs have no idea how to disentangle themselves, but the owners can do it easily because they have the intelligence to visualise the solution. To me, this has nothing to do with language.

Could we be stumped by a puzzle that a higher intelligence could solve easily? I suspect that when intelligence has reached a certain threshold, there is no puzzle that can't be solved, even if it may take longer than for a higher intelligence. Human-level intelligence may even have to devise a computer code to do the work, but it is still our cognition that leads to a solution. ▮

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AI anxieties play out

Science fiction series *Mrs. Davis* and *Class of '09* reflect our disquiet about artificial intelligence as it storms into our lives, says **Josh Bell**

TV

Mrs. Davis

Streaming on Peacock (US); UK to be announced

Class of '09

From 10 May: Hulu (US); Disney+ (UK)

Sister Simone (Betty Gilpin) spent a decade avoiding a mysterious AI

SOPHIE KOHLER/PEACOCK

ARTIFICIAL intelligence has been a staple of science fiction for decades. But now, as it becomes an all-too-real presence in our daily lives, its portrayal in fiction comes with a greater sense of urgency.

Two new shows feature AI as a tool that reshapes the world. *Mrs. Davis* and *Class of '09* take very different stylistic approaches, but both treat AI with scepticism and, often, outright hostility.

The chaotic, playful *Mrs. Davis* sets its AI title character in opposition to a nun who is convinced she is on a literal mission from God, while *Class of '09* offers a more sombre, grounded perspective, with AI as a tool of government control.

In both shows, the lead character finds herself working with an underground network to undermine or even destroy the secretive AI. For *Mrs. Davis*'s Sister Simone (Betty Gilpin), it is akin to a holy war. For *Class of '09*'s FBI agent Ashley Poet (Kate Mara), it is a matter of redemption for the agency to which she has devoted her life. In their own ways, both women are true believers.

It is nearly impossible to summarise the plot of *Mrs. Davis*, a globe-spanning, kaleidoscopic adventure that opens in 14th-century France and goes on to encompass casino stage magic, Super Bowl commercials, bull riding and a castaway named Schrodinger who lives on a deserted island with his cat.

Creators Tara Hernandez and Damon Lindelof fill the show with goofy, tongue-in-cheek references, which help balance out the weightier themes about technology versus religion.

Set mainly in an alternate version of 2023, *Mrs. Davis* presents a world where the sudden appearance of a mysterious AI 10 years before – the eponymous Mrs Davis – has allegedly put an end to hunger, war and unemployment.

> **"It is more likely that the actual AI of the future will resemble Better Tomorrow than Mrs Davis"**

Not everyone thinks this algorithm is a benevolent overlord, and Sister Simone has spent a decade cloistered away from contact with it. But when Mrs Davis decides it has a mission for her, it marshals all its resources to make sure she can't refuse.

The sheer density of twists, fake outs and narrative detours can feel exhausting, but Gilpin holds it together with a witty, charming performance that mixes snark with melancholy. Sister Simone is a vibrant, complex character who is more fascinating to watch than the convoluted story unfolding around her.

Mara has a more straightforward presence, befitting the espionage drama she stars in, which comes from novelist and creator of TV drama *London Spy* Tom Rob Smith. *Class of '09* takes place in three time periods, following Poet and her colleagues as trainees in 2009, as established agents in 2023 and as high-level operatives in 2034.

By then, Poet's former classmate Tayo Michaels (Brian Tyree Henry) has ascended to the position of FBI director and implemented a crime-stopping AI nicknamed Better Tomorrow.

Although the AI was supposed to be a glorified criminal database, it now functions more like the prescient systems in the film *Minority Report* or the TV show *Person of Interest*, initiating arrests for crimes people have yet to commit.

Class of '09 is slow to explore those implications because it devotes substantial time to the characters' early training and to the investigations that shaped their world views. Those episodes are solid but unremarkable cop thrillers, and it is only when the show moves into the future that Smith explores more thought-provoking ideas about the balance between safety and freedom and the supposed "equality" of justice via AI.

There is still plenty of suspense in *Class of '09*, however, and Mara and Henry make for effective opposing forces, gradually finding themselves at odds over the nature of law enforcement.

It is more likely that the actual AI of the future will resemble Better Tomorrow than Mrs Davis, although both systems are suitably frightening. It is that mix of thrill and dread that makes AI so compelling, both in reality and in sci-fi. ■

Josh Bell is a writer and critic based in Las Vegas, Nevada

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Making sense of it all

Predictive processing is one of neuroscience's hottest topics. **Clare Wilson** finds out why in an important guide to the field

Book
The Experience Machine
Andy Clark
Allen Lane

ON A building site, there is a scream of pain. A worker has jumped down from scaffolding and landed on a long nail that is now emerging from the top of his boot. In clear agony, the man is taken to hospital, where his footwear is cut away to reveal that the nail passed between his toes without even breaking the skin. The pain was entirely in the man's head – yet it was very real to him, a paradox explained by Andy Clark in his new book *The Experience Machine: How our minds predict and shape reality*.

In contrast to what we might expect, and what neuroscientists used to believe, the way we perceive the external world isn't just based on raw data coming in through our senses. It is a merging of our brains' predictions combined with that new data.

Known as predictive processing theory, this is one of the hottest topics in neuroscience at the moment, and it has been described as a grand unifying theory of the brain.

The process might seem overly complicated, but in fact it is a very efficient way for our brains to run, explains Clark. Consider how video files are compressed by computers – say, a movie of a man running down a corridor. The only difference between frame 4 and frame 5 is a slight forward motion of the runner, says Clark. All that needs to be transmitted to capture frame 5 are those few differences to frame 4, which take up far less data than a new value for every pixel in frame 5.

For the same reasons, our brains do something similar when interpreting inputs from our senses: making predictions based on existing knowledge and only transmitting onwards the differences, which are known as the "prediction errors". This helps explain why it is so easy to be fooled by optical illusions, as we unconsciously make predictions about the size and distance of objects based on cues from their surroundings.

This can also be illustrated, he says, when you listen to heavily distorted sounds, such as the "Brainstorm/green needle" clip (YouTube: bit.ly/3opzzsD). What you hear changes depending on whether you read the words "brainstorm" or "green needle".

We don't just use predictive processing for external inputs, but also when interpreting internal signals from our bodies. This may account for what are sometimes called psychosomatic illnesses (now often known as "functional disorders"). An example would be someone who is convinced that part of their body is paralysed, despite there being no physical cause.

Some neuroscientists think psychosomatic illnesses could be explained by faulty predictive processing: the conscious belief that the body part is paralysed, say, is overruling the real incoming sensory data. Supporting this idea is the fact that one of the most successful treatments for functional disorders uses distraction techniques that shift attention away from the malfunctioning body part, allowing the real internal data to take over.

As someone who has been involved in the field for years, Clark makes a knowledgeable tour guide – although, if I have one gripe, I would have preferred a more impartial account. Predictive processing can feel like a "just-so" story when it is used to explain any puzzling aspect of the brain, from the placebo effect to our susceptibility to mental illness, without much solid experimental evidence.

Also, we don't yet have good candidates for how predictive processing works at the molecular and neuronal level, but we learn little about these caveats.

Even so, for those who want to know more about an important and growing field of neuroscience, *The Experience Machine* is an excellent primer.

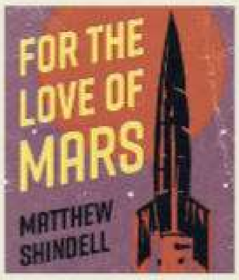
Optical illusions fool us because of the way we make predictions about size and distance

MARIO GYB/ALAMY

Don't miss

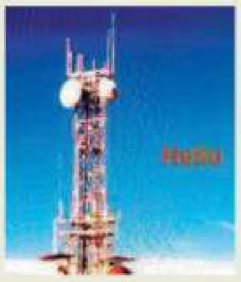
Visit

Destination Cosmos, a collaboration with NASA, allows you to experience the universe through immersive installations spanning stars, planets, nebulae and supernovae. See it at the Hall des Lumières, New York, until 4 June.



Read

For the Love of Mars by Matthew Shindell, US National Air and Space Museum curator, charts our engagement with the Red Planet. The book covers modern exploration and surveys the power Mars has over human imaginations. On sale from 18 May.



Visit

Vertigo is artist Nye Thompson's new exhibition, exploring surveillance, satellites and space. It includes CU Soon, performance art for satellites and humans. At East Quay in Watchet, Somerset, UK, 20 May to 3 September.

NYE THOMPSON, HALL DES LUMIERES

The TV column

Golden age of doom

Apocalypses are everywhere on TV, but for each gem there is one to forget. A new offering, *Silo*, starts from a great premise about a society forced to live underground, but does it really deliver, asks **Bethan Ackerley**

Bethan Ackerley is a subeditor at *New Scientist*. Follow her on Twitter @inkerley

APPLE TV+

Juliette (Rebecca Ferguson) pieces together knowledge from the past

I AM experiencing apocalypse fatigue. I don't mean the numb hopelessness many people feel in response to the climate crisis, but a weariness with the explosion of fictional cataclysms on TV.

For every gem like *The Last of Us* or *Station Eleven* there is an utterly forgettable show with little to add to a crowded canon. With the bar raised so high, it has never been harder for writers to make their own takes stand out.

The latest post-apocalyptic show battling for the spotlight is *Silo,* based on Hugh Howey's series of books of the same name. With the planet irrevocably poisoned and the air itself toxic, humans have retreated deep underground. Just one sensor provides a view of the blighted ruins outside. All knowledge of what caused this degradation and how long the silo has existed was lost in a rebellion 140 years before the show begins.

The silo is stratified across its 144 levels, with elites living in relative luxury "up top" and the most desperate languishing in "the down deep". Inhabitants are assigned jobs that are essential to maintaining their home, from farming to IT, while order is upheld by a sheriff, an elected mayor and a murky judicial department dedicated to the "pact", the rules set down by the silo's founders.

Life there veers towards the totalitarian. To control the population, sexual relationships must be sanctioned and women are implanted with mandatory birth control, while the right to attempt to become pregnant is governed by a lottery. Artefacts that predate the rebellion or are from the "before times" are illegal and may get you banished outside the silo, where you are politely asked to clean the sensor before you succumb to the noxious air. If you want to go outside, you can, but you can't change your mind.

> **"Who built the silo? What happened in the rebellion? Is the world really polluted? The mysteries draw you in"**

Silo's concept sets it apart from a sea of lesser shows: the culture of this underground society, from such minutiae as its hand-painted mugs to community events like the foot race up the silo's central staircase, can be fascinating.

So, too, are the ways that the silo's inhabitants piece together knowledge from the before times, as protagonist Juliette (Rebecca Ferguson) reverse engineers the tools she needs to fix a watch, while IT engineer Lukas (Avi Nash) rediscovers patterns of star constellations through the sensor's restricted view.

Equally interesting is the nature of the doom that drove humanity underground. We have seen so many zombie or viral apocalypses on TV that it is refreshing to see pollution as the threat du jour.

But there are too many ways in which *Silo* doesn't make the grade. The first episode, Freedom Day, is poorly written and focuses too heavily on Holston (David Oyelowo), the silo's unlikeable sheriff who refuses to act on the evidence of wrongdoing his wife Allison (Rashida Jones) uncovers.

Juliette is only introduced after an hour of heavy handed exposition, in which *Silo* barks questions at its audience rather than priming them to ask. Who built the silo? What happened in the rebellion? Is the world really polluted? The mysteries draw you in over the 10-episode season, but when answers are provided, some hinge on implausibilities and sweeping generalities that collapse under scrutiny.

Silo may well be a victim of its time, arriving amid some stellar post-apocalyptic shows. Despite its compelling premise, it needed to be better to make a dent in this oversaturated market. ▮

TV
Silo
Apple TV+
Streaming from 5 May

Bethan also recommends...

TV
Station Eleven
HBO (US); StarzPlay (UK)
Based on the novel by Emily St. John Mandel, Station Eleven *is a story about the power of art in a world ravaged by a deadly flu outbreak.*

The Last of Us
HBO (US); Sky and Now (UK)
This much-celebrated adaptation of the bestselling video game follows a smuggler and a teenage girl crossing the US 20 years after a fungal infection destroyed most of civilisation.

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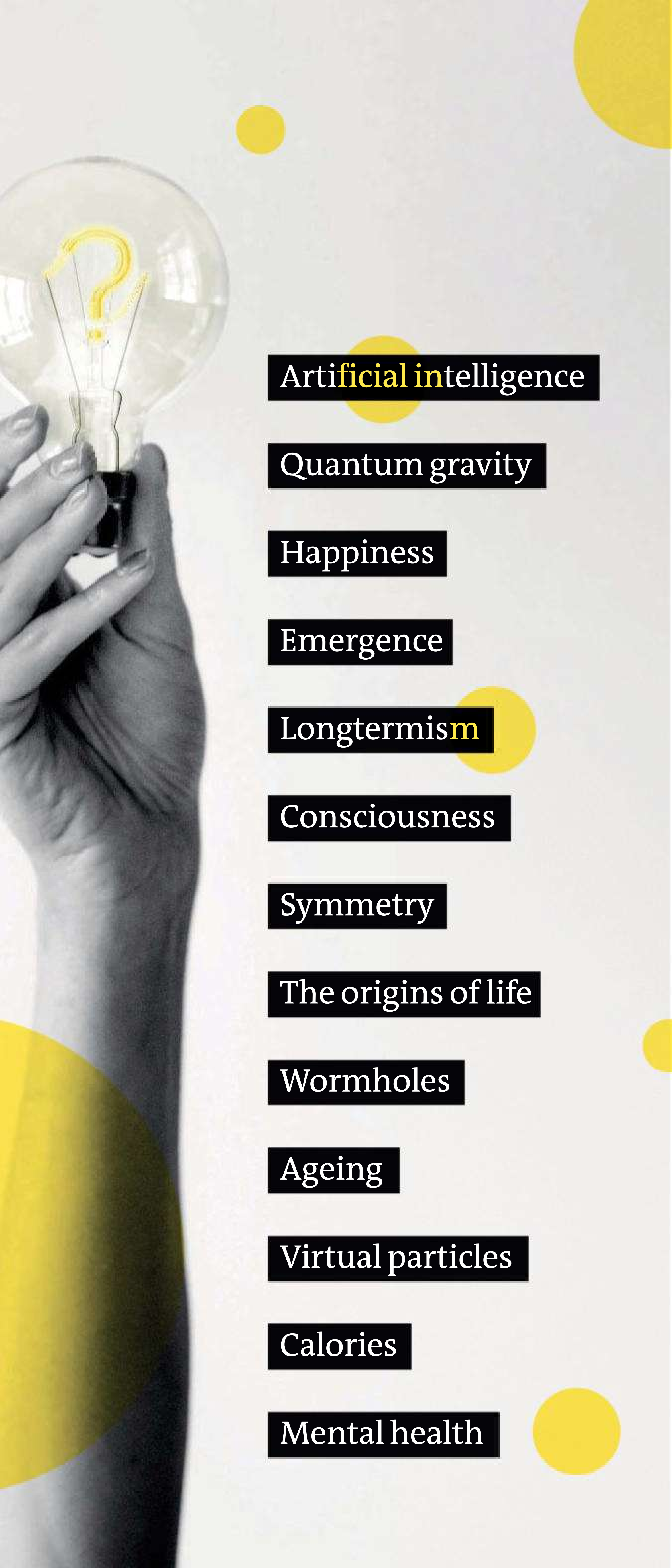
HOW TO THINK ABOUT…

Science has taken us a long way in our quest to make sense of an often-enigmatic universe and our place in it. But this is a never-ending story, with new evidence and fresh ideas constantly reshaping how we think about some of the hardest questions – and the concepts that help us unravel them, from calories and happiness to consciousness and quantum gravity.

Some of these seem almost ludicrously difficult to get your head around, while others might feel familiar and yet are far more complex than they first appear. That's why, over the following pages, we present a clear-eyed guide to 13 of the most mind-bending and surprisingly interesting concepts in science by exploring how the experts think about them



- Artificial intelligence
- Quantum gravity
- Happiness
- Emergence
- Longtermism
- Consciousness
- Symmetry
- The origins of life
- Wormholes
- Ageing
- Virtual particles
- Calories
- Mental health

ANETE LUSINA/PEXELS / LEONELLO CALVETTI/ALAMY

How to think about…
Artificial intelligence

WHAT do paper clips have to do with the end of the world? More than you might think, if you ask researchers trying to make sure that artificial intelligence acts in our interests.

This goes back to 2003, when Nick Bostrom, a philosopher at the University of Oxford, posed a thought experiment. Imagine a superintelligent AI has been set the goal of producing as many paper clips as possible. Bostrom suggested it could quickly decide that killing all humans was pivotal to its mission, both because they might switch it off and because they are full of atoms that could be converted into more paper clips.

The scenario is absurd, of course, but illustrates a troubling problem: AIs don't "think" like us and, if we aren't extremely careful about spelling out what we want them to do, they can behave in unexpected and harmful ways. "The system will optimise what you actually specified, but not what you intended," says Brian Christian, author of *The Alignment Problem* and a visiting scholar at the University of California, Berkeley.

That problem boils down to the question of how to ensure AIs make decisions in line with human goals and values – whether you are worried about long-term existential risks, like the extinction of humanity, or immediate harms like AI-driven misinformation and bias.

In any case, the challenges of AI alignment are significant, says Christian, due to the inherent difficulties involved in translating fuzzy human desires into the cold, numerical logic of computers. He thinks the most promising solution is to get humans to provide feedback on AI decisions and use this to retrain models so their output is aligned with human preferences. This is the approach OpenAI uses to prevent its large language models like GPT-4 from providing harmful responses.

But Dan Hendrycks, director of the Center for AI Safety, a San Francisco-based non-profit organisation, says there are more fundamental challenges. Human values are complex, nuanced and highly dependent on context. Moreover, how modern AIs make decisions is often opaque. "It is difficult to understand, let alone control, the intrinsic motivation of something whose inner workings are so inscrutable," says Hendrycks.

Some AI researchers reckon alignment is a fool's errand. There is always going to be a trade-off between an AI's capabilities and our ability to control it, says Roman Yampolskiy at the University of Louisville in Kentucky. He claims to have shown, through theoretical work, that the key ingredients required to control AI – predicting and explaining its decisions, verifying that it follows its design and setting well-defined goals – are fundamentally impossible when faced with superintelligence.

The truth is that it isn't at all clear we are on an inexorable march towards artificial superintelligence, says Melanie Mitchell at the Santa Fe Institute in New Mexico. This means it may be better to worry about nearer-term harms of unaligned AI. Either way, there is reason to believe the whole endeavour might be fatally flawed.

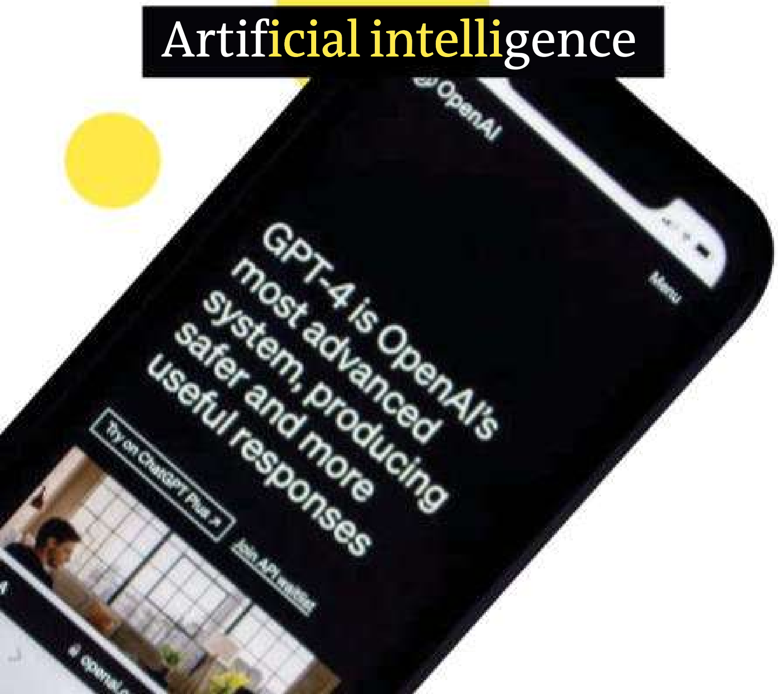
All the evidence from neuroscience and psychology suggests the development of intelligence in humans is intrinsically linked to our goals. It therefore seems unlikely that you could transpose human values onto a machine developed under entirely different circumstances. "A truly intelligent system would really have its own values and its own goals that are influenced by everything it has learned, in the same way that we are," says Mitchell.

But Scott Aaronson at the University of Texas at Austin says it is far too early to throw in the towel. The only rational approach is to focus on aligning existing AIs and hope this provides lessons we can build on as the technology advances. "It is hard for me to imagine how you would align an extremely powerful AI if you already don't know how to align much weaker AIs," says Aaronson.

Edd Gent

KOSHIRO K/ALAMY

Artificial intelligence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How to think about… Quantum gravity

MODERN physics has two stories to tell about our universe. The first says it is fundamentally made of space-time: a continuous, stretchy fabric that has ballooned since the dawn of time. The other says it is fundamentally made of indivisible things that can't decide where they are, or even when.

Both stories are compelling, describing what we observe with incredible accuracy. The big difference, though, is the scale at which they apply. Albert Einstein's theory of general relativity, which describes gravity, space and time, rules over very massive objects and cosmic distances. Quantum physics, meanwhile, governs tiny, sprightly atoms and subatomic particles.

Ultimately, both stories can't be true. Nowhere is this more apparent than at the big bang, where everything in the universe was compacted into an infinitesimally small point. Here, you need a single theory that encompasses gravity and the quantum realm. "Why we're here is the big question," says Toby Wiseman, a theorist at Imperial College London. "It seems that quantum gravity is the only answer."

Alas, it is an answer we are yet to find, despite many decades of searching. Quantum gravity means a reconciliation of the continuous and the indivisible, the predictable and the random. There are many ideas, but none can totally incorporate everything. "We're still no better off at understanding the beginning of space and time," says Wiseman.

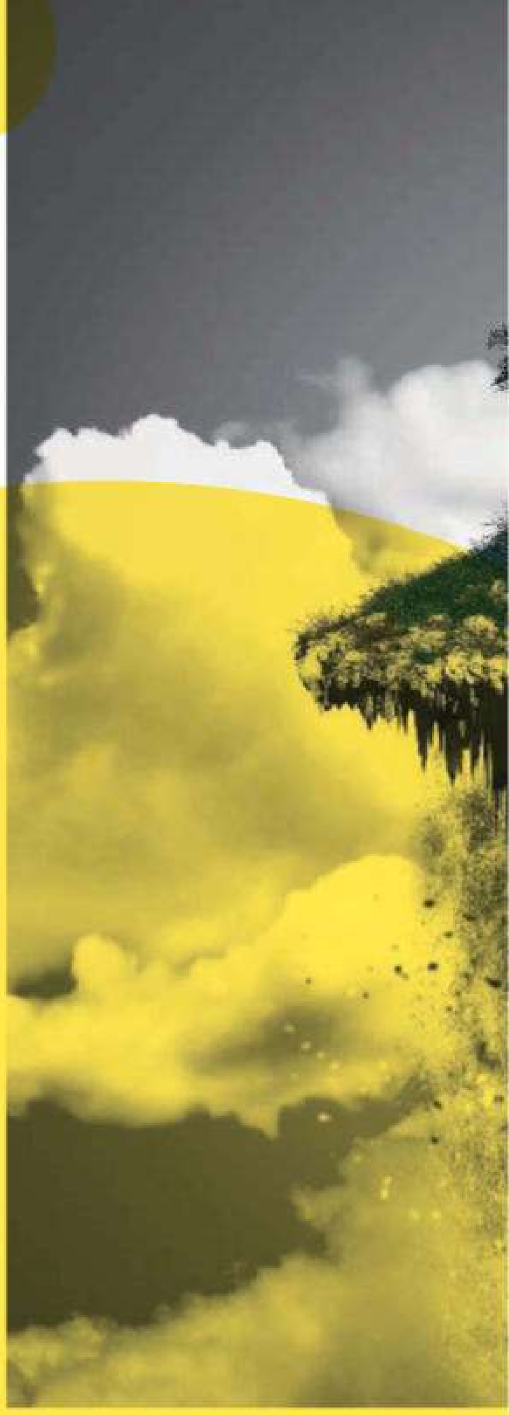
Most physicists attempting this begin with quantum physics, the workhorse of which is quantum field theory. This describes three of the four forces of nature – electromagnetism, the strong nuclear force and the weak nuclear force – by "quantising" them as force-carrying elementary particles. It is only a matter of time, you might think, until gravity is shown to be the effect of another quantum force-carrier, known as the graviton.

In practice, however, gravity has proved nigh-on impossible to quantise. In the calculations required, it throws up senseless infinities that, unlike those for the other forces, can't be tamed. Worse, Einstein's gravity is unique in that it equates to the geometry of space-time, the very stage on which the other forces act. If gravity becomes just another force, what happens to this stage? This is why most quantum field theories start off with space-time as a given. "You sort of have to assume something," says Nick Huggett, a philosopher at the University of Illinois in Chicago.

One alternative is to build space-time itself out of indivisible units, such as the loops and foams proposed by a theory called loop quantum gravity. Another option, and the one that is currently more popular, was inspired by a mathematical conjecture called the AdS/CFT correspondence, which suggests that gravity can pop out of a quantum field theory at some cosmic boundary, like the hologram on the back of your credit card.

This holographic correspondence only works in an abstract "toy model" of space-time very different to our own. Still, it has convinced many in the field that rebuilding space-time from the bottom up may be unnecessary. Instead, space-time may emerge naturally from more fundamental mathematical relationships.

Jon Cartwright



KIPARGETER/FREEPIK

How to think about…
Happiness

MORE than 2300 years ago, Aristotle argued that happiness was the highest good. Later, the US founding fathers considered its pursuit to be an unalienable human right. These days, you will find countless books promising to reveal the secrets of a happy life. But have millennia of philosophical and scientific enquiry taught us anything about how to achieve that?

First, let's look at how people who study happiness measure it. One of the most common strategies is to ask people to rate statements such as "In most ways, my life is close to my ideal" and "If I could live my life over, I would change almost nothing". These aim to capture someone's overall satisfaction with life, rather than their mood on a specific day.

That makes sense, says Richard Layard, co-director of the Community Wellbeing Programme at the London School of Economics, because asking people to sum up their general contentment is often more practical than measuring their emotional state over an extended period. The other thing, says Layard, is that general contentment fits better with philosophical definitions of happiness as an overarching quality, as opposed to transient pleasures.

Using this kind of scale, psychologists have attempted to identify the specific ingredients that contribute to happiness. Contrary to the idea that "money can't buy happiness", income does play a role: it is easier to feel pleased with your lot when you don't have to worry about bills and can treat yourself to luxuries. We are also influenced by the riches of others – we are less happy if we know our neighbour is earning more than us. "We can be doing well, but our minds choose reference points that make us feel crappy," says Laurie Santos, a cognitive scientist at Yale University and host of *The Happiness Lab* podcast. This is one reason why higher levels of inequality in a society lead to lower levels of life satisfaction.

Surprisingly, our life satisfaction may be written in our genes as well as our bank balances. According to a study of twins in Norway, around 30 per cent of the variance in people's life satisfaction is inherited. This seems to be related to personality traits known to be partially shaped by our genes. Extroversion, for instance, is linked to greater social support, which contributes to greater happiness. Neuroticism, meanwhile, makes it harder to deal with life's stresses.

DNA isn't destiny, however: science offers many evidence-based strategies to boost happiness. Since loneliness is one of the primary causes of unhappiness, much of this advice aims to help us build stronger social bonds. Talking to strangers, volunteering and performing random acts of kindness have all been shown to leave you feeling more contented.

The trick is not to let the pursuit of happiness overwhelm you. When people were asked to write down 10 things that could make them happier in the future, or 10 things that showed they were happy now, those who performed the first task recorded a greater sense of "time scarcity" – the feeling that the years are slipping away – and their life satisfaction dropped as a result.

I call this the "paradox of happiness" in my book *The Expectation Effect*. The good news is that it can be solved by shifting your focus from the future to present pleasures, says Sam Maglio at the University of Toronto in Canada – the "small shots of happiness that fill our daily lives". Tuning in to those is a quick and easy way to feel happier, he says: "Since I've started taking my own advice, I find more happiness from the same things that I've always done by seeing them as the goal, not a stepping stone to greater happiness."

David Robson

> "LIFE SATISFACTION MAY BE WRITTEN IN OUR GENES AS WELL AS OUR BANK BALANCES"

How to think about…
Emergence

YURI ARCURS/ALAMY

Emergence

THE next time you get caught in a downpour, don't think about how wet you are getting – but how you are getting wet. Rain is, after all, just molecules composed of hydrogen and oxygen atoms, and there is nothing wet about hydrogen or oxygen on their own. There isn't even anything wet about a single water molecule. Put lots of them together in the right conditions, however, and you will get wet.

The wetness of water is an example of an "emergent" property: a phenomenon that can't be explained by the fundamental properties of something's constituent parts, but rather manifests only when those parts are extremely numerous. Emergent phenomena are ubiquitous in nature and a proper grasp of how they come about could hold the key to solving some of our biggest mysteries. "There is a sense in which nothing in science makes sense without emergence," says Erik Hoel, a neuroscientist and author based in Cape Cod, Massachusetts.

In physics, for example, some materials exhibit superconductivity, where large numbers of electrons can move without resistance, and yet it isn't always clear why. Neuroscientists, meanwhile, find that consciousness seems to emerge from some collective behaviour of neurons. In both cases, simply understanding the basic constituents of the system doesn't explain the phenomenon in question, never mind allow you to recreate it from scratch. "Ultimately, we want to explain under which circumstances we will see novel properties," says Larissa Albantakis, a computational neuroscientist at the University of Wisconsin-Madison.

But the study of emergence is, by turns, promising and maddeningly difficult. The standard "reductionist" approach to scientific investigation breaks large-scale, or macroscopic, systems down into their constituent microscopic parts to deduce the laws that govern those parts. It doesn't work when we are faced with emergent systems, which may explain why we haven't yet cracked room-temperature superconductivity or consciousness.

"We have to get a better understanding of how the interactions between more microscopic parts of a system connect with the macroscopic behaviour of the same system," says Albantakis. The problem is that "while the word 'emergence' gets thrown around a lot, there is not enough rigorous, quantitative work on the subject", she says.

Jessica Flack at the Santa Fe Institute in New Mexico is among those aiming to change that. For starters, she wants to better characterise the different degrees of emergence, so we have a better chance of coming up with an explanation of how it works. Some systems, for example, are strongly "screened off" – meaning that changes at the micro-scale make very little difference to the emergent behaviour. "One task for science is to start quantifying this variation in screening off," says Flack.

This way, a form of reductionism would work on emergent systems. It would be possible to do experiments that knock out certain variables, meaning researchers could characterise macroscopic behaviour in a way that allowed them to work backwards to microscopic characteristics.

Flack says it is similar to inferring the statistical properties of gas molecules by examining how pressure, temperature and volume affect each other. We might not be able to identify a single or precise cause, but we can identify a family of microscopic configurations or patterns of interactions that underlie the emergent behaviour.

Hoel has a different approach, known as "causal emergence", which seeks to identify the scale at which a system's variables have the strongest causal effects on each other and hence on the emergent property. A model of the system at this scale will be more informative about important features of the system, he says. The goal, of course, is to crack mysteries like superconductivity and consciousness. And Hoel reckons there is no reason to think there is anything special about those systems. "I don't think emergence is some rare or magical quality, but almost stupidly common," he says.

Michael Brooks

How to think about… Longtermism

IMAGINE a child, running barefoot through a forest, and a broken glass bottle buried just beneath the soil. What's worse: that a present-day child steps on the shards, or that a child in 100 years from now does?

This question, posed by philosopher Derek Parfit in the 1980s, was intended to clarify our moral obligations towards unborn generations. Knowingly risking harm to a future person, he argued, is just as bad whether it is today or in a century.

Parfit's ideas inspired a branch of moral philosophy called longtermism. It rests on three premises: future people matter, there could be a lot of them and we have the power to make their lives better or worse. Ensuring the future goes well should therefore be a key moral priority of our time.

All of which seems reasonable, at first glance: it apparently promotes the universal values of stewardship, the duty to posterity and being a "good ancestor". But longtermism has proven controversial, with some critics arguing that it is a "dangerous ideology" that permits or even encourages the suffering of people alive today.

Is that fair? To make up your own mind, the first thing you need to know is that longtermism comes in different flavours. Many of the most strident criticisms focus on the implications of "strong longtermism", a variant introduced in a 2021 paper by the University of Oxford's Hilary Greaves and William MacAskill, which says that it should be the top moral priority of our time.

This would have striking consequences for how money is spent in the real world. Indeed, it is already having an influence. The leading advocates of longtermism work in the world of billion-dollar philanthropy and "effective altruism", where huge sums are allocated to causes based on reasoning about the world's most pressing problems and the most efficient ways to tackle them. Longtermism has tangibly shaped how foundations and billionaire donors spend their money on research, activism and political races.

Existential dangers

Right now, many longtermists are more worried about the existential dangers posed by artificial intelligence than, say, social justice or homelessness. And it is this willingness to rank distant, hypothetical risks above the needs of people alive today that makes them unpopular. Even those who study existential risk, such as Carla Zoe Cremer at the University of Oxford and Luke Kemp at the University of Cambridge, worry that longtermist efforts are bypassing democratic controls and serving the interests of elite, unelected technocrats.

But there's more. For many, longtermism is inherently unpalatable and dangerous because the number of future people could be enormous, and a moral framework that accounts for all their needs inevitably dwarfs those of people alive today. The fear is that longtermism could evolve into a form of mathematical blackmail, where reducing existential risk by a small percentage in 1000 years, say, seems a better use of resources and leads to the neglect of immediate problems like climate change. It might even justify harmful acts in the name of the greater, future good.

With all that said, it is important to note that longtermism is still evolving and its strongest form isn't the only version of it. Among others, there is weak longtermism, which simply says we should seek ways to ensure the future goes well: this would be one moral priority, but not necessarily top of the list. Which version, if any, will find greater influence remains to be seen.

Parfit was aware that the questions he posed lacked simple answers. It took another generation to fashion his ideas into longtermism. Now, amid the controversy, perhaps it will require a new generation to figure out where longtermism goes next.

Richard Fisher

BEN ROBERTS/PANOS PICTURES

How to think about… Consciousness

IF YOU had to point to the place where consciousness emerges, you would probably aim your finger squarely at your head. That is the easy bit. Exactly where the brain circuitry for consciousness lies, or how the physical properties therein seemingly transform into the subjective feeling of being, are questions that have bamboozled us for centuries. And it turns out that we might have been looking in the wrong place all along.

The brain on its own isn't enough to generate subjective experience, says Catherine Tallon-Baudry, a neuroscientist at the Ecole Normale Supérieure in Paris, France. Without the body, the self simply wouldn't exist. "Just as the notion of 'car' exists only if a certain number of components are present and interacting with each other," she says. Instead, researchers have come to recognise that our sense of interoception, which monitors

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internal body signals – such as heart rate, pain, thirst and pleasure – plays a major role in creating our thoughts and emotions. Now, many consider interoception to be a fundamental feature of consciousness, too.

Our internal organs, particularly the heart and gut, are key players in building our conscious experience, says Tallon-Baudry. Both have their own self-generated rhythm, separate from the brain – and this, Tallon-Baudry believes, provides a handy hook on which the brain can hang its sense of self.

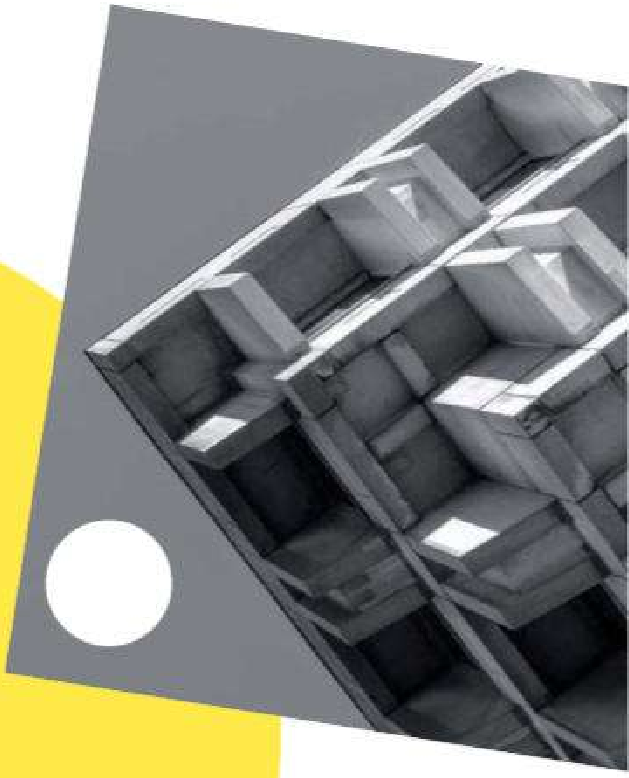
Taking the idea a step further, Antonio Damasio at the University of Southern California says that internal body signals aren't just involved in consciousness – they are consciousness. "People continue talking about consciousness as the great mystery that will be revealed by understanding the brain, and that's wrong," he says. "It's not about the brain, it's about what the brain achieves with the interoceptive system in the body."

In this view, the brain is still involved, but more in an operational role. Conscious thought allows us to respond to what the body is saying, "but you are not conscious because of the cognition", says Damasio. What's more, he believes that the body-centred view of consciousness makes the question of how physical matter gives rise to conscious experience, known as the hard problem, disappear. "I don't think it exists, because these feelings generate a constant perspective," he says. "It is the construction of a self."

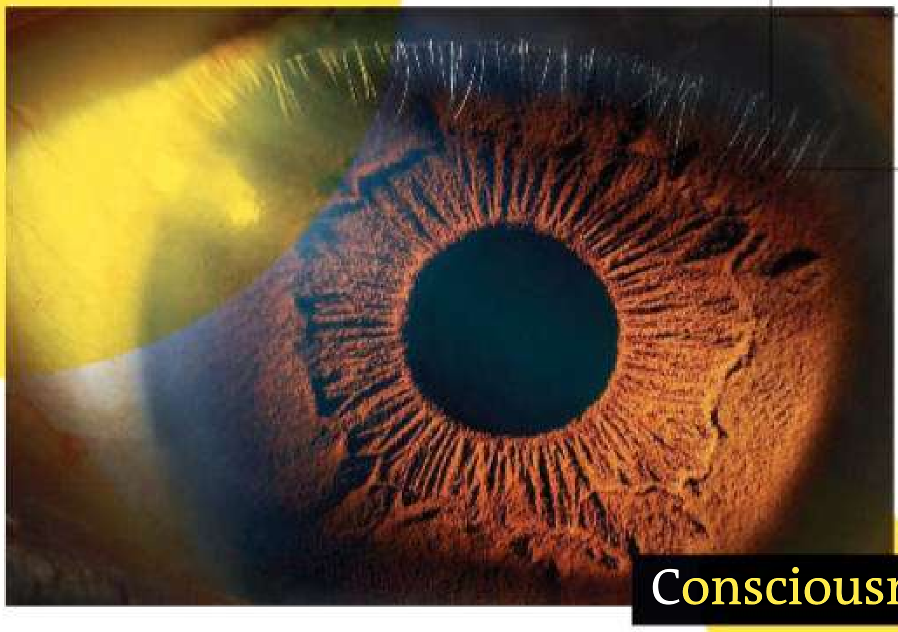
Not quite, says Hugo Critchley at the Sussex Centre for Consciousness Science, UK. "Thinking about low-level feeling states as primordial consciousness is probably the way to go, and then the expectation is that everything builds up from that," he says. "But that's where it gets really complicated." This idea of consciousness arising in the body still doesn't explain how physical processes turn into that feeling of being "you", says Critchley, nor how consciousness allows us to mentally travel back and forth in time.

Even so, few in the field today believe that consciousness is an entirely brain-based phenomenon. "Bodily explanations are a step toward understanding how subjective experiences can arise from biological material," says Tallon-Baudry. "In that sense, they are a step toward solving the hard problem."

Caroline Williams



"THE BRAIN ALONE ISN'T ENOUGH TO GENERATE CONSCIOUSNESS"



PETER FINCH/GETTY IMAGES

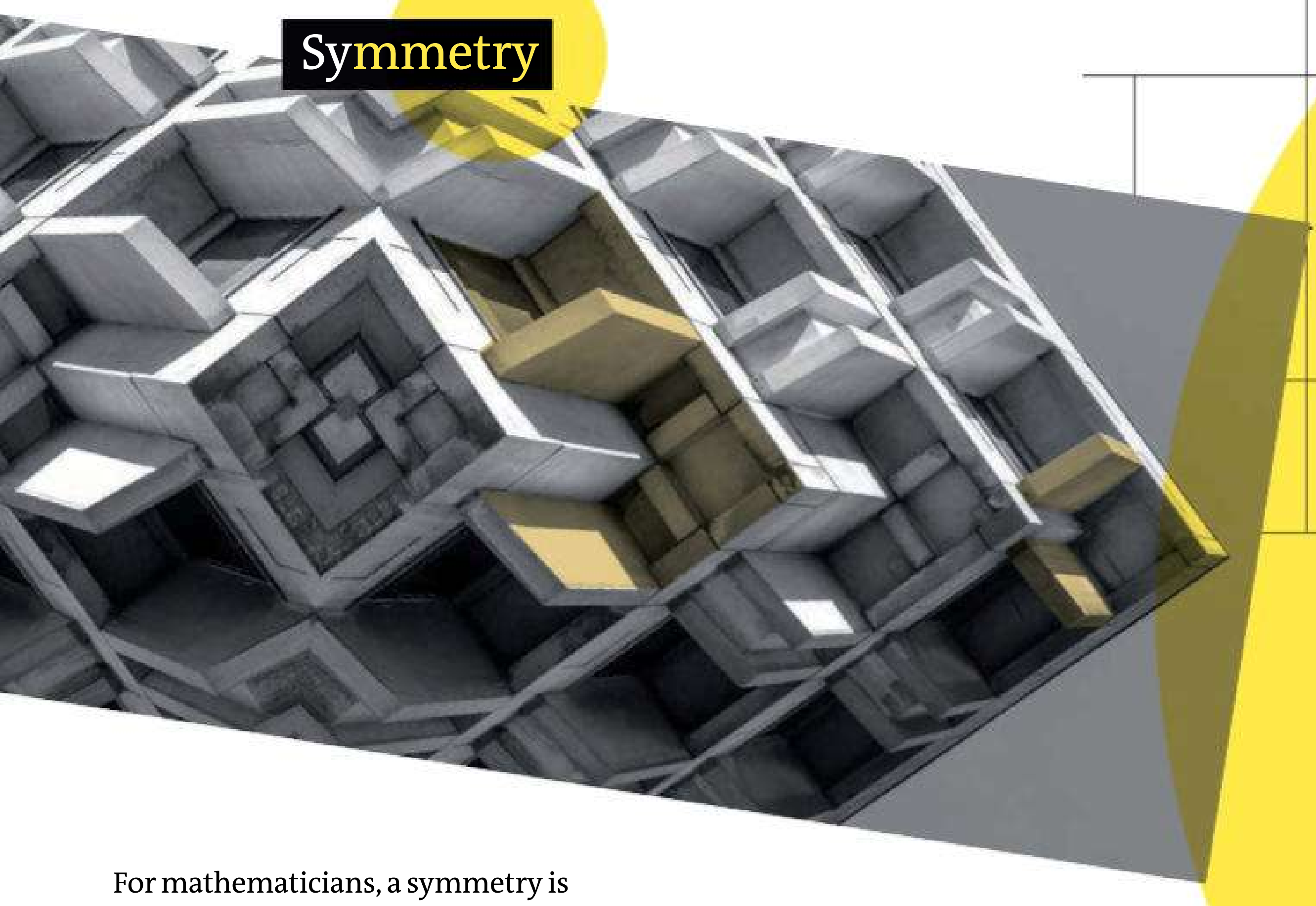
Consciousness

How to think about… Symmetry

YOU might remember learning about symmetry at school. Maybe a teacher showed you a snowflake's six-fold symmetry and you marvelled at how it looked the same no matter how you rotated it. Well, it turns out that the wonders of symmetry go a whole lot deeper – as any mathematician who has studied it will tell you.

"Instead of being something visual, which is what I responded to as a child, it became something much more abstract and linguistic in nature," says Marcus du Sautoy, a mathematician at the University of Oxford. "The understanding of symmetry I have now is so much deeper and stranger, and it gives me access to symmetries that are so much more exotic than anything you can see with your eyes."

Symmetry



STEVE PANCRATE/PEXELS

For mathematicians, a symmetry is a type of invariance – when something remains unchanged under some kind of transformation, such as flipping it or rotating it. That sounds simple enough, but, as du Sautoy suggests, most symmetries go beyond what is obvious to a casual observer.

Consider antimatter, which is what you get when positively charged particles become negative and vice versa. If no significant effects occur, then the system involved has charge symmetry. The laws of physics as we understand them suggest that the very early universe should have had equal amounts of matter and antimatter and then immediately annihilated itself. The fact that this didn't happen means there was no charge symmetry in the newborn universe – understanding why is one of the biggest tasks in physics.

Matter's symmetries aren't just a laundry list of things that are invariant under some change, however. They can relate to each other in ways that produce new symmetries. "There is a series of well-studied particle models whose symmetries live one inside the other, like a set of Russian dolls," says Nichol Furey at Humboldt University of Berlin. "Symmetries themselves can have symmetries!"

This richness reflects the importance of the concept in physics. Symmetry has proven particularly useful in developing theories because it is usually an indication that something can be simplified. That is how we built the standard model of particle physics, which makes sense of matter and its workings. We defined its symmetries and the identity of all the particles it contains. Everything else, such as the dynamics and interactions of all the particles, can be derived from this, says Jonas Lindert at the University of Sussex, UK. "Symmetry is absolutely fundamental to particle physics."

Physicists are especially interested in symmetries that disappear or "break". The existence of the quark was predicted thanks to an observation of broken symmetry. And the search for the Higgs boson was motivated by the need to break a symmetry of the early universe in order to account for the mass of the W and Z bosons.

All of which raises the question: why is symmetry so vital to the universe? Du Sautoy thinks it is an indication of the fundamental role mathematics plays in reality. "My belief is that what we see around us is a physicalised piece of mathematics," he says. Whether that is true or not is another debate entirely. But Lindert is confident that symmetry is going to be key to future discoveries in physics. "Symmetry will always be absolutely fundamental in any new theory of nature," he says.

On that point, Sabine Hossenfelder at the Frankfurt Institute for Advanced Studies in Germany, is more circumspect. Ancient symmetry-centric notions that the planets' orbits should be circular and modern ideas of supersymmetry, where each known particle should have a hidden partner, haven't stood up to scrutiny. "Symmetry is sometimes misleading," she says.

Michael Brooks

How to think about… The origins of life

"IT IS one of these big questions that we truly are clueless about at this point," says Lena Vincent at the NASA Jet Propulsion Laboratory in Pasadena, California. "Anyone who says otherwise, I would be sceptical of."

Which isn't to say we are short of ideas for how life on Earth began. On the contrary, all manner of hypotheses have been put forward to explain how non-living chemicals might self-assemble into a living organism. Some rely on hypothetical self-replicating molecules, some on blob-like structures that could have been the predecessors of cells, while others focus on complex cycles of chemical reactions.

Yet none of these ideas has gained widespread acceptance, never mind led to a definitive experiment. As a result, thinking about life's origins is an exercise in reasoning under uncertainty. It is about how to tell the difference between a truly promising idea and one that merely has a veneer of plausibility.

The truth is that we can't know for sure exactly how life began on Earth, says Vincent. "We just don't have access to the part of history on this planet that would allow us to verify that." The best we can ›

do is to demonstrate processes that produce life and show that they are compatible with what we know about the early Earth.

For that reason, Vincent prefers to talk about "origins of life", to avoid implying that we are studying a single, specified event. It "may have happened many times", she says, and "may be continuing to happen" somewhere in the universe.

What is important is whether an experiment seeking to demonstrate how life began is plausible; is it reasonable to suppose that something like it happened somewhere on Earth billions of years ago? Here, again, we face uncertainty: little is known about what the planet was like when it was young, so almost anything can be argued to be "plausible".

The best we can do is attempt to recreate essential processes of life, such as metabolism or replication. "An interest in the processes, regardless of what they are, to me is more interesting than just finding a molecule," says Joseph Moran at the University of Strasbourg in France.

The problem is that we don't know which of life's processes came first, and therefore which we should be seeking to demonstrate in the lab. For example, by comparing the DNA of distantly related organisms, biologists have partially reconstructed the Last Universal Common Ancestor (LUCA): the species from which all living organisms today are descended. Unfortunately, it turns out LUCA was complicated, with hundreds of genes and proteins. There must be a long prehistory of life prior to LUCA, about which we know virtually nothing, so we can't use LUCA to figure out which of life's processes came first. "Simply saying that something is universal does not constitute an argument [that it came first]," says Eric Smith at the Earth-Life Science Institute in Tokyo, Japan.

Experiments have produced increasingly complex chemical systems that aren't alive but have some of the features of life. However, these chemical systems are still a far cry from even the simplest known forms of life. Smith says that one of our biggest issues is that we have no idea what the intermediate stages looked like.

A key challenge will be to identify the bottlenecks that prevent non-living chemical systems from becoming more complex. The most promising molecules and processes will be those that offer ways through those bottlenecks, says Smith. "This is why I think the origin of life will turn out to remain an interesting and fun problem for quite a long time."

Michael Marshall

PLAINPICTURE/KAROLINA DOLEVICZENYI

The origins of life

How to think about… Wormholes

IN YOU go and out you pop – in a galaxy far, far away. Such is the incredible promise of the wormhole, a hypothetical portal in which space-time funnels into a narrow passage only to open up somewhere else, possibly on the other side of the universe.

It sounds fantastical, but 50 years ago many said the same about black holes, which also involve highly warped space-time. "We study wormholes partly for fun and partly, more seriously, to see what is physically allowable for space-time," says theorist Toby Wiseman at Imperial College London. "And of course – who knows – perhaps one day, in the very far future, this could be an actual technology."

Despite their mythic reputation, there is nothing especially outlandish about wormholes. They are predictions of Albert Einstein's general theory of relativity, which says that mass creates gravity by warping the fabric of the universe. General relativity has allowed for an ever-enlarging universe, the big bang and black holes. In that context, wormholes seem no more far-fetched. In fact, Einstein himself was one of the first to provide a mathematical description of them, in the mid-1930s.

"The great thing about general relativity is that you can write down any space-time you want, plug it into the Einstein equations and translate it into what matter you would need to support it," says Wiseman. So if you want space-time to look like a wormhole, you need a certain sort of matter.

What sort? The trick is to find something that can prop open a wormhole without it collapsing straight away. In 2020, Juan Maldacena at the Institute for Advanced Study (IAS) in New Jersey and Alexey Milekhin, then at Princeton University, predicted that matter that interacts via gravity alone could produce a wormhole big enough for humans to fit through. However, we are yet to identify matter that interacts via gravity alone, such as the dark matter thought to keep galaxies from flying apart, with the characteristics required. "As far as we know, this construction can't actually be embedded in our universe," says Wiseman.

Then again, ordinary matter could generate traversable wormholes, according to Ping Gao at the Massachusetts Institute of Technology, Daniel Jafferis at Harvard University and Aron Wall at the IAS – albeit in a type of upside-down model universe in which gravity emerges as a "holographic" property. Their trick was to employ the quantum property of entanglement, by

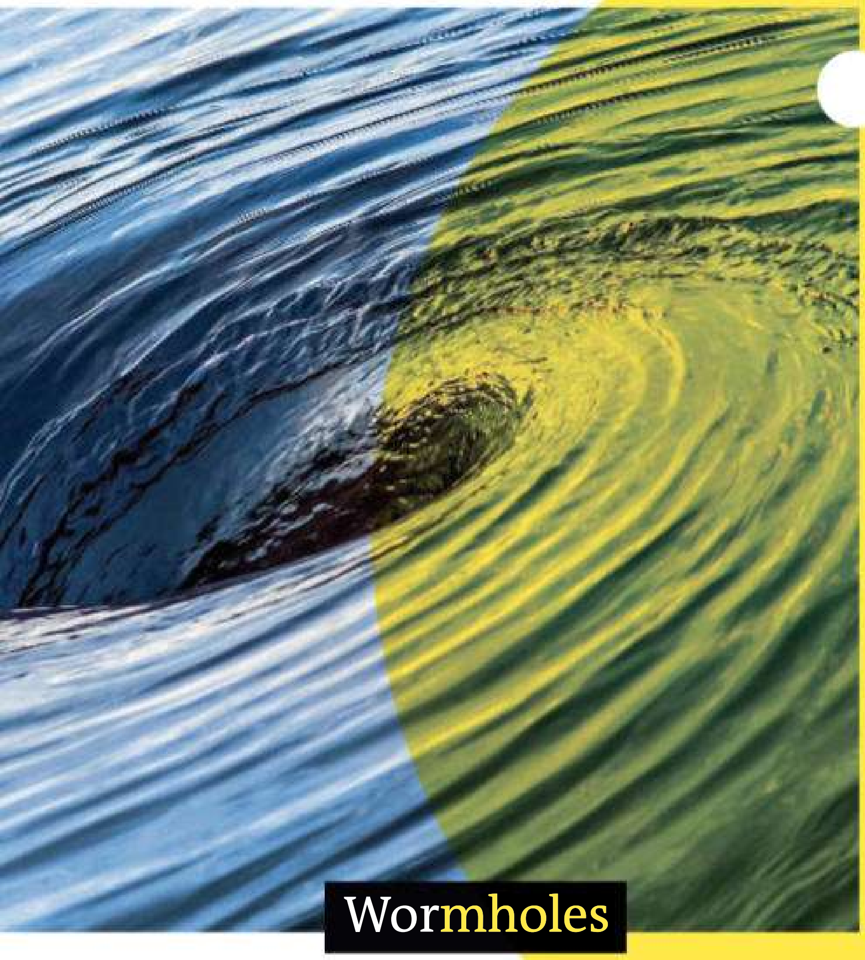
LEONID IKAN/SHUTTERSTOCK

which measurements on one particle can instantaneously affect the properties of another, an arbitrary distance away. Performing measurements on pairs of particles entangled over a wormhole would stop the wormhole collapsing, they say.

Proof of this concept seemed to arrive last year when Jafferis and others claimed to have simulated a wormhole on Google's Sycamore quantum computer, with the transport of a particle from one quantum chip to another. But Norman Yao at the University of California, Berkeley, and his team disputed the claim, saying that whatever happened didn't bear the hallmarks of holographic gravity and therefore wasn't a wormhole proper. Hrant Gharibyan at the California Institute of Technology says it was more like conventional quantum teleportation: "The hardware needed [to simulate this type of wormhole] might be another 10 years away."

Still, we don't live in the upside-down universe in which these wormholes could exist. Besides, any passage through a wormhole would demand negative energy to keep it open during transit. Quantum physics permits some of this, but only so much. The result, says Wiseman, is that passage though wormholes, if they exist, is almost certainly forbidden to be quicker than any conventional route. "If this is true, there's no shortcut," he says.

Jon Cartwright



"THE IDEA IS VERY MUCH THAT AGEING IS GOING TO BE PREVENTABLE"

How to think about…
Ageing

IT HAPPENS to everyone who lives long enough, gradually at first and then suddenly. By the time we are in our 50s, most of us have at least one age-related health condition. By 85, almost all of us do, and typically several at once. Cancer, diabetes, cataracts, osteoarthritis, dementia. The list could go on and on.

None of which is surprising, at least to those of us old enough to have experience of ageing. What you may not be aware of, however, is that we now have a comprehensive understanding of ageing at the molecular and cellular level. Even more surprising is the growing consensus that ageing can be slowed or even reversed. "The belief that ageing is treatable is still there, there are optimists everywhere," says Linda Partridge, director of the Max Planck Institute for Biology of Ageing in Cologne, Germany. "The idea is very much that it's going to be preventable."

Why we age has been debated for many years. There are two schools of thought. One is that it is the accidental but inexorable accumulation of damage to cells and biomolecules. The other is that ageing is biologically programmed, the evil twin of our development from embryo to adult.

Both hypotheses have evolution at their heart in the form of "reproductive fitness" – the ability to pass our genes on to our children. The damage-accumulation hypothesis argues that when we are young, it pays to invest in cellular repair processes to maximise that fitness. But after a certain age, that investment is no longer worth its cost, at which point repair processes falter and damage accumulates. The programmed hypothesis counters that evolution has selected for a "suicide" programme that causes us to stop reproducing and drop dead, clearing the way for the carriers of our genes and maximising their reproductive fitness – which is, indirectly, ours.

In practical terms, why it happens hardly matters. The ageing process is the same regardless, and it contains multitudes. A lot of the damage happens to DNA, which accumulates mutations and becomes unstable. The ends of chromosomes erode and the pattern of chemical tags that can turn genes on and off, called epigenetic markers, changes in a way so predictable it can be used to estimate biological age.

Plenty of other things fall apart, too. The intracellular waste-disposal system, known as autophagy, grinds to a halt; cells and tissues clog up with clumps of damaged protein and other detritus; the ability to sense sugars and other nutrients is blunted; mitochondria, the engines of our cells, become less efficient at producing energy; some cells become cancerous while others turn into zombies; stem cells stop dividing; low-level inflammation creeps throughout the body; and the gut microbiome becomes less healthy. All of these "hallmarks of ageing" have been shown to contribute to age-related conditions.

The extent to which we now understand these processes is good news, because all these hallmarks have shown promise that they might be treatable. One of the criteria for the hallmarks is that each must be amenable to intervention, and all of them have passed that test – mostly in mice and rats, though some human trials have also been successful. Already, there are promising signs that it may be possible to lower epigenetic age, reboot autophagy, rejuvenate mitochondria, refresh nutrient sensing, clear out zombie cells and restore gut microbiomes to full health.

This hardly constitutes a fountain of eternal youth, but it does explain the confidence that we can intervene in ageing. It may not lead to longer lives, but it will increase healthspan – that is, the number of healthy years before age-related conditions start piling up. And that is how we will think of ageing: as a health problem that can be treated, albeit never cured.

Graham Lawton

ISLANDSTOCK/ALAMY

How to think about… Virtual particles

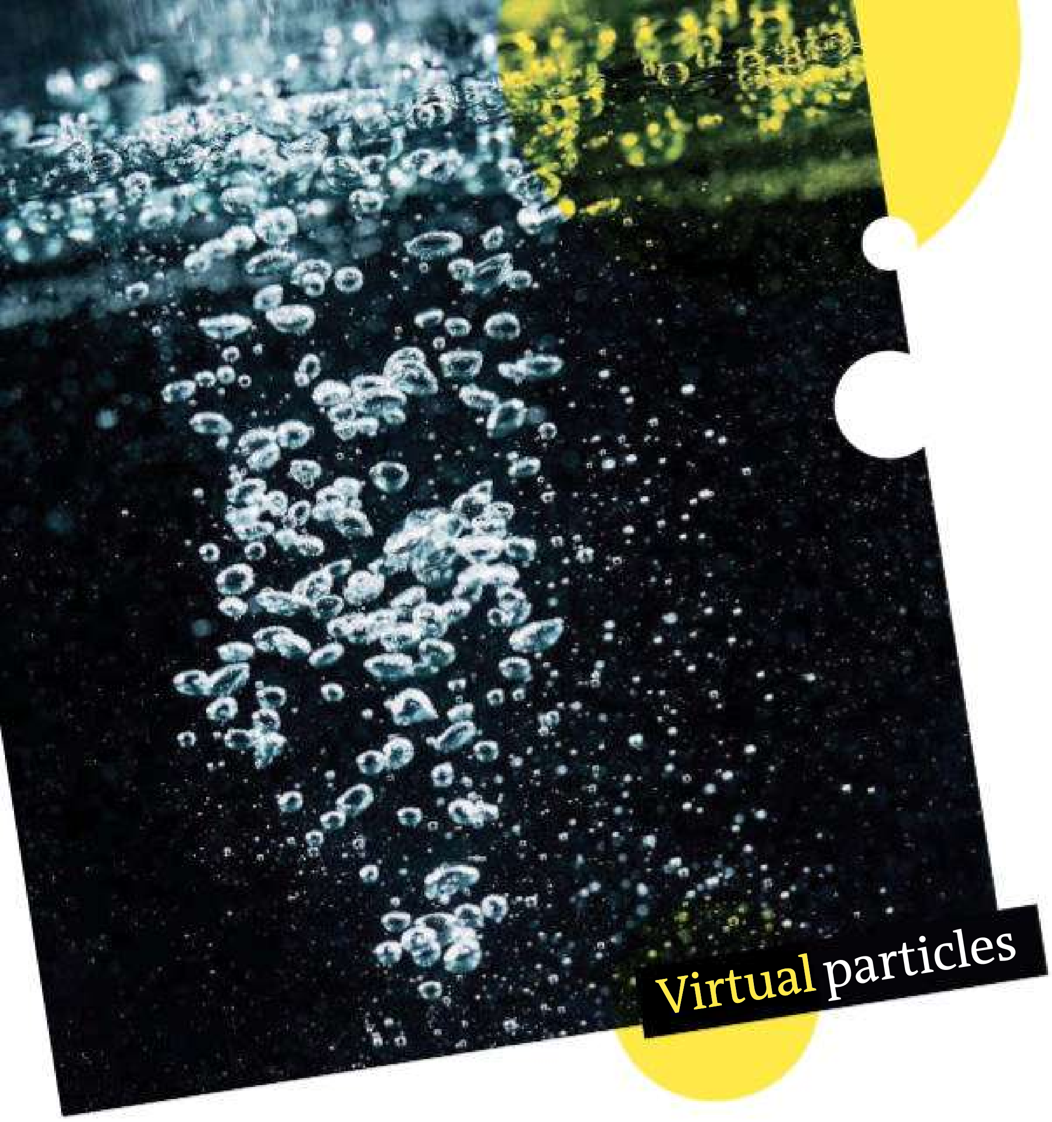
THE first thing you need to know is that virtual particles, which are impossible to avoid if you want to understand how the fundamental forces of nature animate matter, aren't really particles at all. "The language makes people misunderstand," says Matt Strassler, a theoretical physicist at Harvard University. The second is that they might not be proper physical constituents of the universe.

Let's start with some basics. According to quantum theory, our best description of the subatomic realm, particles aren't the infinitesimal snooker balls we tend to imagine, but excitations in underlying quantum fields. The Higgs boson is a spike in the underlying Higgs field, for instance, and electrons are spikes in the electromagnetic field. These fields permeate the entire universe, but we can't observe them directly. What we see are particles – clear disturbances in a field that persist over time and interact with other, similar disturbances to produce more particles.

Virtual particles are more subtle. So subtle, in fact, that although they can be thought of as disturbances in underlying fields, they don't persist for long – and can't be directly detected. This is where things get confusing, because virtual particles do appear to affect the properties and behaviour of other particles in measurable ways. They seem to be emitted and absorbed by real particles when those particles interact, which is why we rely on virtual particles for our understanding of how three of the known fundamental forces – electromagnetism and the strong and weak nuclear forces – work.

Another common misconception is that virtual particles appear out of nothing. "The usual story we tell is that a virtual particle is something that emerges from the vacuum, enjoying a brief, ephemeral existence before disappearing again," says David Tong at the University of Cambridge. "While this is sometimes a useful analogy, I don't think it captures what's really going on."

That is because nothing is created from nothing. "There is always energy involved in one way or another," says Christine Aidala at the University of Michigan. A better way to think about it, she says, is to return to the



“DON’T CONFUSE THE MATHS WE USE TO DESCRIBE REALITY WITH REALITY ITSELF”

idea that everything is made of fields – and recall that those fields interact with each other in complicated ways, creating ripples that constantly change.

The question of whether virtual particles are real or are merely a mathematical tool arises because they were invented – or discovered, depending on your point of view – when physicist Richard Feynman created squiggly line diagrams to render tractable the equations physicists use to describe particle interactions.

Today, some argue that virtual particles are real because we can observe the effects of them. But “what that really means is that I can detect a physical effect which can be calculated using the methods of virtual particles”, says Strassler. “You are never actually seeing the virtual particles.”

Nima Arkani-Hamed at the Institute for Advanced Study in New Jersey is similarly unconvinced. Feynman diagrams, as they are known, remain the best method we have to account for particle interactions, he says, but we shouldn’t confuse the maths we use to describe reality with reality itself.

In fact, Arkani-Hamed is among those trying to do away with virtual particles. He has been working on a radical new way to calculate particle interactions – by invoking an abstract mathematical object called an amplituhedron. Maybe one day, then, these ephemeral, endlessly confusing “particles” will disappear once and for all.

Abigail Beall

COTTONBRO STUDIO/PEXELS

How to think about… Calories

WHEN you are navigating the complex world of nutrition, the calorie feels mercifully simple. A straightforward measure of the energy in our food, calories sit at the heart of conventional weight control advice. Consume too many, or fail to burn enough, and you will put on weight. Want to slim down? Eat less and move more. As the saying goes, “a calorie is a calorie is a calorie”. Dig a little deeper, however, and you find it isn’t that simple.

This idea of the body as a furnace and food as its fuel was popularised by Wilbur Atwater in the 19th century. He deduced that there are three main components, or macronutrients, with which we can calculate the calorie content of any food: protein and carbohydrates contain 4 calories per gram, while fats contain 9. Combine these and the result informs the calorie content on food labels everywhere.

But think about how food is consumed and you hit your first problem. Take an orange, says Giles Yeo, a geneticist at the University of Cambridge and author of *Why Calories Don’t Count*. An orange is mainly carbohydrate, or sugar. “When you drink orange juice, your body will absorb the sugar [quickly] because there is no digestion required,” says Yeo. Eat orange segments, however, and it takes energy for the digestive system to work on the fibre and extract the sugar. “Physiologically, your body does completely different things with it, with exactly the same calorie hit,” says Yeo. Orange juice causes a more rapid spike in blood sugar levels than the orange segments, for example, and regular surges in blood sugar levels can increase the risk of many conditions, from diabetes to dementia. The orange segments also take longer to reach the gut, stimulating hormones that help us feel full.

Next, throw in the effects of cooking. The body uses energy to digest food. Cooking is essentially an extension of digestion: it breaks down ingredients, making it easier for the body to extract the energy. For processed and cooked foods, the calorie count you see on labels is most likely to be an underestimate. A stick of raw celery has about 6 calories in it, for example. “If you cook that stick of celery, that 6 calories becomes 30,” says Yeo.

Atwater’s calculations also fail to account for the cost of digestion. Protein may contain 4 calories per gram, but because of the work needed to digest it, we will only ever extract 70 per cent of those, says Yeo. ›

This is why labels on foods containing protein overestimate calories.

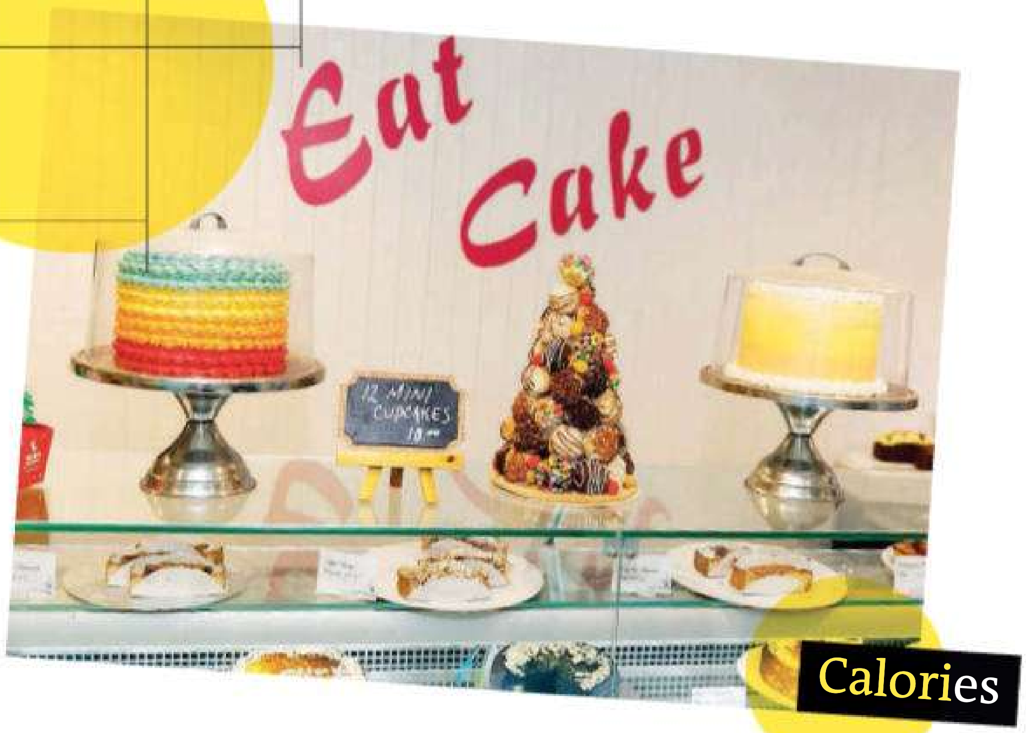
The other thing to consider is that people can respond very differently to the same food, resulting in huge variations in weight gain and fat distribution. And finally, calories vary in their nutritional content. A lollipop contains roughly the same number of calories as a small apple, for instance, but consuming lots of nutritionally "empty" calories will soon take a toll on health.

So much for the "calories in" side of the equation. But "calories out" is equally bamboozling. We think of exercise as a "big lever" to get rid of excess calories, says Herman Pontzer at Duke University in North Carolina. But work by Pontzer and others looking at various populations, from hunter-gatherers to ultra-runners and sedentary desk workers, has found that pretty much everyone burns around the same number of calories each day no matter how much exercise they do.

Pontzer's suspicion is that the body adapts to increased exercise in ways that we don't fully understand. Exercise is great for overall health – but it doesn't help much with weight loss, which suggests the solution to obesity isn't quite as simple as eating less and moving more.

The upshot is that the body isn't just a furnace. It has a sensitive thermostat, constantly adjusting to the environment. So while calories are temptingly simple at first glance, we have to reckon with the complexity of the human body.

Catherine de Lange



Calories

MARTIN PARR/MAGNUM PHOTOS

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How to think about… Mental health

THESE days, we are increasingly aware that mental health problems can be as debilitating as physical ones. Unfortunately, much of what we thought we knew about what causes mental illness has recently turned out to be wrong.

In a way, this shouldn't be surprising, says Allen Frances at Duke University in North Carolina, lead author of a major US psychiatry textbook, the *Diagnostic and Statistical Manual of Mental Disorders IV*. "The brain is the most complicated thing in the known universe, and it reveals its secrets very slowly," he says.

A couple of decades ago, we seemed on the verge of unlocking the secrets of several mental health conditions. The cause was thought to be irregular levels of various brain chemicals, which could be remedied with drugs. Depression, for example, was thought to stem from a lack of the brain signalling chemical serotonin, partly because the most common kind of antidepressants raise levels of this compound. Genetic studies also found that people with depression were more likely to have a gene variant that lowers serotonin. Schizophrenia was thought to be caused by excess activity of circuitry involving a different brain chemical, called dopamine.

But this neat picture turned out to be a mirage. The latest evidence suggests that low serotonin isn't a cause of depression, and many early genetic studies that implicated single brain chemicals as a cause of specific conditions were carried out using scientific methods now considered to have been flawed.

Mental health conditions do have a strong heritable component. For instance, someone whose identical twin has schizophrenia has about an 80 per cent chance of developing the condition themselves. But the genetics are complex. The most recent genetic studies show that more than 100 gene variants influence our risk of depression, for example, each with only a tiny impact.

Common causes

Every other mental health condition investigated so far is similarly influenced by multiple genes. And many of the same genes are involved in predisposing people to what are usually thought of as very different conditions, including depression, anxiety, bipolar disorder and obsessive compulsive disorder. "We've given up on a small number of genes explaining any mental illness," says Frances.

The genetic revelations have lent support to a recent idea that, rather than being a set of discrete entities, all mental health conditions may have their roots in a common underlying cause, sometimes called the "p factor". The idea is that these gene variants together make the brain more vulnerable to mental illnesses. Perhaps which condition someone develops depends on different external triggers or even chance events.

What that vulnerability may consist of isn't clear. In April, a large brain-scanning study suggested it could be down to insufficient "pruning", the process of getting rid of unhelpful connections between brain cells, which begins in early childhood but intensifies in adolescence. "It's a single underlying neurobiological factor," says Barbara Sahakian at the University of Cambridge.

This is unlikely to be the final word, though, especially as brain-scanning studies have a long history of producing divergent results that even experts can't agree on. Perhaps the most important thing to understand about mental illness, then, is how much we have yet to understand. ▮

Clare Wilson

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Debunking gardening myths

Water, water everywhere

It is a long-held idea that midday watering will scorch plants' leaves – but this isn't supported by evidence, says **James Wong**

James Wong is a botanist trained at London's Kew Gardens who shares his tiny flat with 500 houseplants. @botanygeek

AS A botanist, gardening has – unsurprisingly – fascinated me since I can remember. However, it isn't only the mysteries of plants that I find so full of wonder, but also the colourful, and often puzzling, human behaviour we see in the world of horticulture.

Steeped in centuries of received wisdom, gardening's many "rules" have been repeated so often they can seem like incontrovertible truths. This is despite scientific trials demonstrating that many have little basis in fact, so following them may be unnecessary at best and could give you inferior results at worst.

A classic example is the long-held idea that watering plants around noon on a sunny day should be avoided, since it might harm their leaves. The explanation is that tiny water droplets can act like lenses, focusing the sun's rays onto sections of leaves just like a magnifying glass would, resulting in scorched foliage and reduced plant health.

This belief has even been cited by professional foresters as the cause of wildfires. Given the devastating impact these can have, it is pretty astonishing that the first scientific article on the topic wasn't published until 2010.

Four researchers – most of whom were at Eötvös Loránd University in Hungary – set out to learn more, running experiments on living plants and carrying out computer modelling. They found that spreading small glass spheres over the surface of smooth-leaved plants could indeed have this "magnifying glass" effect, causing damage right across the leaf surface. But when this was repeated with actual water droplets, such damage didn't occur.

RBKOMAR/GETTY IMAGES

This is because water behaves rather differently to glass. Firstly, the shape of a water droplet on a leaf is more elliptical than spherical. The computer modelling showed that the maximum damage through a lens of this shape would occur when the sun was at a low angle in the sky, so in the morning or in the afternoon.

However, the sun's intensity at these times is too low to cause any harm. Even if the intense light of the midday sun did somehow come at the most potent angle, the heat at this time of day would invariably cause the water droplets to evaporate before they had an effect.

The moral of the story? If your plants are in need of a good watering, give them some water. Not watering thirsty plants on a hot and sunny day for fear of leaf scorch will almost certainly lead to more damage from drought stress than could be caused by the magnifying glass effect. While it remains generally true that the ideal time to water a plant is in the morning or evening – to lessen the amount of water that evaporates before reaching the plant's roots – the evidence doesn't support the idea that watering at midday will cause burning.

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Debunking gardening myths appears monthly

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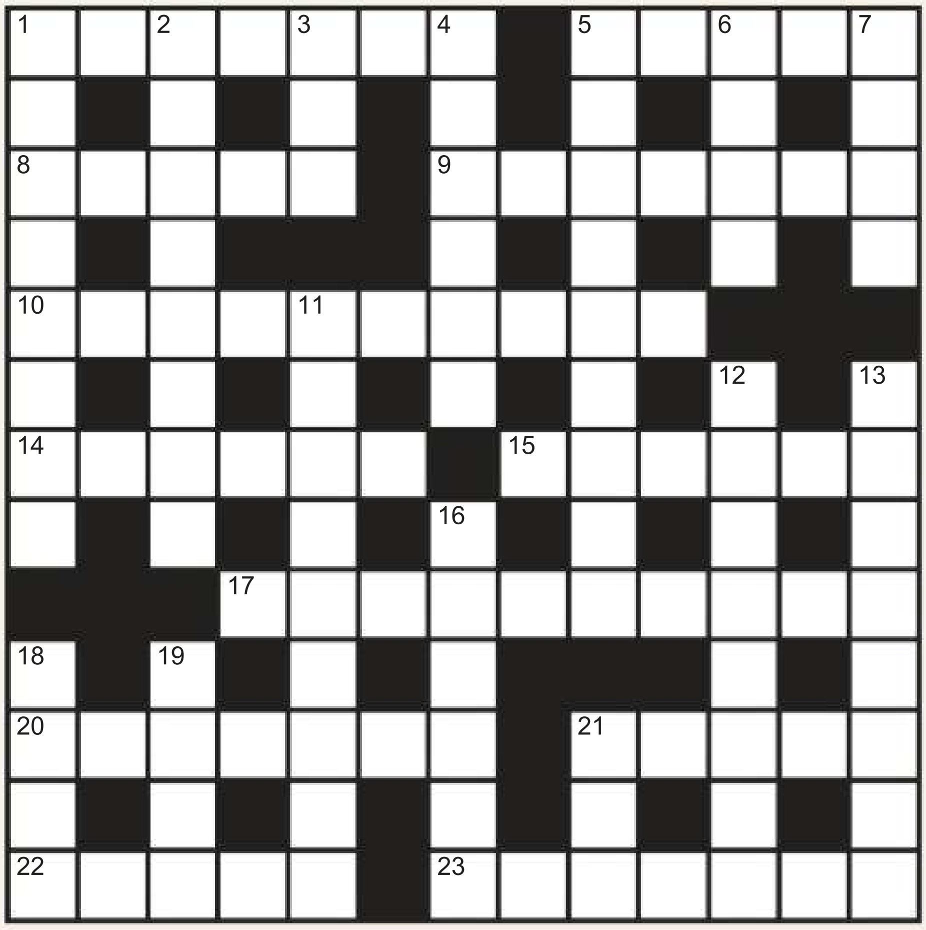
Cryptic crossword #109 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

1 System of rules accompanies popular energy drug (7)
5 Squirrel away money for audit (5)
8 Hungry male interrupts disorganised type (5)
9 Geneticist's single hard opal crushed by finger (7)
10 Transport vehicle and protruding flap don't have darkest coating (10)
14 Good ring-shaped foundation (6)
15 Layers street paving material east to west by mid-May (6)
17 Engineer seen in pursuit of more complete buckyballs and the like (10)
20 Business scam at world's largest particle physics lab (7)
21 Hotel commissionaire retains service provider (5)
22 Mopes all over town famous for magnesium sulphate (5)
23 Core set chooses bag for Spooner (3-4)

DOWN

1 Constant stirring gave ale mineral property (8)
2 Trust editor backing writer over Mafia boss (6,2)
3 One extremely veiny climber (3)
4 Formerly robust way to get rid of carbon dioxide (6)
5 Superhero accessory clipped cast member clutching current electronic device (9)
6 Boast of ruminant crossing river (4)
7 Swirl bit of Dunkelfelder by day in middle of vineyard (4)
11 Pair of Americans supporting a DNA application to an excessive degree (2,7)
12 Flower producer revised main goal (8)
13 Timekeeper covers answer page's key (4,4)
16 Replicates retinal cells capturing 20 per cent of light (6)
18 Spots expert bottling nitrogen (4)
19 Signs facing away from golf course (4)
21 Put a strain on fasteners, reportedly (3)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #201
set by Bethan Ackerley

1 Papilionoidea is a superfamily of which kind of insect?

2 What name is given to the current geological era, spanning from the extinction of the dinosaurs to the present day?

3 Trees and other plants that produce "exposed" seeds that aren't protected by an ovary or fruit are known as what?

4 Cherenkov radiation often produces flashes of light of which colour?

5 The steroid cortisol is produced by which of the body's glands?

Answers on page 55

Puzzle
set by Colin Beveridge
#221 Logical World Cup

"Drat," said Ron the reporter. "Now the Logical World Cup is over, the editor wants to know how many games each team won, drew and lost, but all I have are the points totals."

"Maybe I can help," said Martha the mathematician. "Show me what you've got."

Ron passed her the sheet of paper he had been glaring at.

	Played	Points
And/orra	5	12
Booleivia	5	10
Truenisia	5	8
Peruf	5	6
United Gates	5	4
Vennezuela	5	2

"Hm. I presume it was a round robin with three points for a win and one for a draw?"

"But of course," said Ron.

"Then I can tell you the other columns," said Martha. Can you?

Solution next week

Whale of an issue

Why do no other aquatic animals grow to a huge size like whales do?

Richard Swifte
Darmstadt, Germany
Although the largest fish is the whale shark, which can typically weigh 20 tonnes, closely followed by the basking shark, this is far exceeded by various whale species. The largest is the blue whale, which averages 150 tonnes.

The buoyancy of water enables ocean animals to grow to greater sizes than land animals, which need legs sturdy enough to support them. But several dinosaur species are estimated to have reached 70 or 80 tonnes, so it seems surprising that no modern sea creatures other than whales have come anywhere near what should be possible.

The largest whales and fish aren't active predators, which would require speed and agility, but feed by passively taking in water and filtering out plankton or other small organisms.

> "The whale shark can reach 13 metres in length and 22 tonnes. This fish is bigger than all but a few of the whale species"

Various possible reasons have been suggested for why fish don't reach the size of whales, which are mammals. Whales have lungs and breathe in air with its 21 per cent oxygen content, while fish use gills to absorb oxygen from water at much lower concentrations. Less oxygen intake could limit the maximum size achievable.

Another idea is that mammal hearts have a double circulation whereby blood goes to the lungs at low pressure to obtain oxygen, and is then pumped separately round the body at higher pressure. Fish hearts are simpler and drive a single, lower-pressure heart-gills-body-heart circulation that is slower at providing nutrients to the tissues. In truth, though, the exact reasons for smaller fish sizes are still uncertain.

Stephen Johnson
Eugene, Oregon, US
While it is true that the biggest oceanic creatures are the large baleen whales, there are other creatures in the ocean whose size overlaps with many whale species.

The order Cetacea, to which all whales belong, has around 89 species and ranges from the world's largest animal, the blue whale, with a length of up to 30 metres and a weight of 200 tonnes, down to river dolphins under 2 metres. Many fish overlap the size range of whales and dolphins, in particular the filter-feeding sharks.

These include the whale shark, which can reach 13 metres and 22 tonnes. This fish is bigger than all but a few of the whale species. In addition, manta rays, great white sharks and sunfish can all reach 3 metres and weigh around 3 tonnes, again more than most cetaceans. Finally, let's not forget the elephant seal, which can reach 5 metres and weigh over 3 tonnes.

Rebecca Helm
Georgetown University, Washington DC, US
Why stop at the size of a whale? Siphonophores – entities formed of a colony of tiny clone animals called zooids – and jellyfish can be longer than whales. And corals can also grow massive, though we often don't think of any of these life forms when we think of big things in the ocean.

[Ed. – Recent research shows that the world's largest whales (rorqual whales, including blue and minke whales, that carry out a lunging movement to engulf huge amounts of water) need to be very big to consume enough food to survive.]

OLGA MILTSOVA/ALAMY

Do ice cubes melt more slowly in warmer climes than cooler ones?

This week's new questions

Cool melt **In Spain recently, in temperatures around 34°C, the ice cubes in my drink took far longer to melt compared with at home, where it is much colder. Why the difference?** ***Penny McDonald****, Robin Hood's Bay, North Yorkshire, UK*

Wheely dirty **Why are the front wheels of my car always much dirtier than the rear ones?** ***Rob Jones****, Shetland, UK*

Frosty formations

Why did these strange ice patterns form on a glazed door (pictured right)? They don't appear on other glass from the same source.

David Muir
Edinburgh, UK
If you observe a glass of fizzy drink, you will see that streams of bubbles originate from definite points called nucleation sites. These are microscopic aberrations on the glass surface that facilitate the liberation of dissolved carbon dioxide gas from the liquid.

The formation of ice crystals is also promoted by nucleation sites. This is demonstrated by water being supercooled to well below its freezing point, but with no ice formation if the vessel holding it is highly smooth, with no nucleation sites. The ice patterns in the picture have crystallised at nucleation sites on the glass door, which, at some point in its existence, has been scratched. These scratches may be difficult to see in daylight. They can be easier to detect in the dark, using a torch pointing at an angle to the glass.

Celia Berrell
Hervey Bay, Queensland, Australia
In response to this question, I wrote a poetic answer.

Frosty Window Pane
Fractal fingers jab and curl
like jagged knife and leafy swirl.
Jack Frost's patterned composition
forms through vapour's deposition.

Water goes from gas to solid.
Missing out the stage of liquid.

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Tom Gauld
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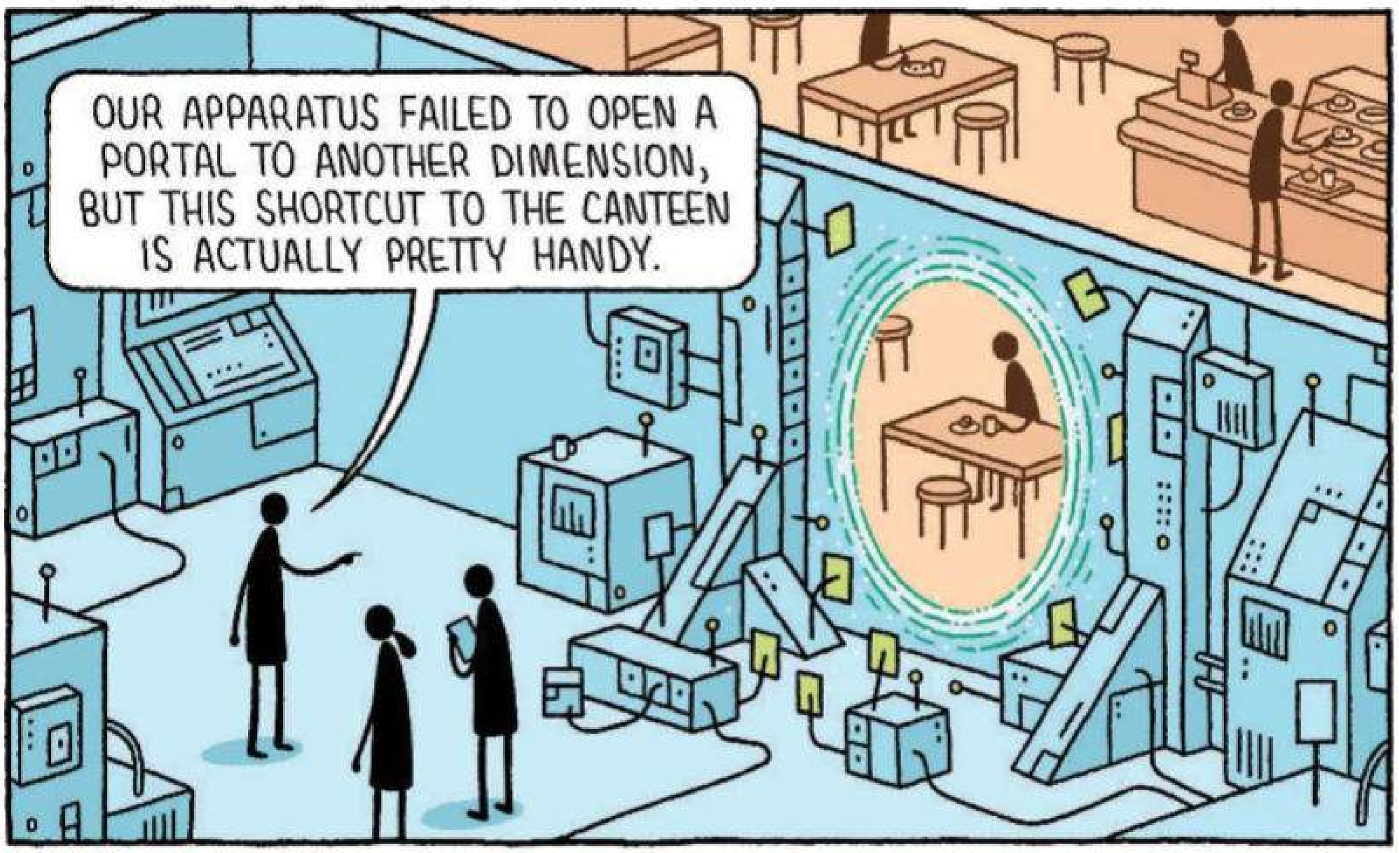

OUR APPARATUS FAILED TO OPEN A PORTAL TO ANOTHER DIMENSION, BUT THIS SHORTCUT TO THE CANTEEN IS ACTUALLY PRETTY HANDY.

Touching freezing window glass
forms crystals from air's water gas.

Blobs of dust, smudged
grease and grime
inspires ice crystal's frost design.
A window pane that's pristine clean
won't grow such pretty,
frosty scenes.

Yawning gap

Is it possible to yawn without closing your eyes? If not, why? (continued)

Steve Jacques
Leicester Medical School, UK
As an anatomist, I have often wondered about yawning, specifically the nerves that are involved in this process.

Most of the nerve supply to the head comes from the cranial nerves, which emerge directly from the brain. There are 12 classically described cranial nerves and the one that has the most to do with yawning is the facial nerve. This supplies many muscles and stimulates secretion from glands in the head. I am sure that it is no coincidence that it supplies the following specific structures: the orbicularis oculi muscle (the one that closes the eyes), the digastric muscle (that opens the mouth), the stapedius muscle (which disengages the middle ear bones from the cochlea to help protect against damaging noise levels), the salivary glands in the floor of the mouth and the lacrimal (tear) glands.

This explains why, when we yawn, we open our mouths, close our eyes, go temporarily deaf, tear up and sometimes even shoot a bit of saliva from our mouths. All of these actions will be coordinated by a centre, one that is probably in the brain stem and sends signals to the facial nerve.

One final thing. Ever seen a fish appear to yawn when it opens its mouth and gill covers? Needless to say, in fishes the gill cover muscles are supplied by the facial nerve.

Paul Entwistle
Liverpool John Moores University, UK
Even harder than keeping your eyes open when yawning, is yawning and making the related body movement with just one arm, which I tried due to injury.

Having recently broken the outer end of my right clavicle (collarbone), I was told that, while it was mending, I should aim not to raise this arm above shoulder level. The clavicle rotates when the outstretched arm is raised more than 90 degrees up from the chest and this rotation interferes with the two broken ends of the clavicle uniting to heal.

But yawning with just one arm stretching out high is very difficult as one automatically stretches out and raises both arms simultaneously. Try it! ▮

Answers

Quick quiz #201
Answers

1 Butterflies
2 The Cenozoic Era
3 Gymnosperms
4 Blue
5 The adrenal glands

Quick crossword #132 *Answers*

ACROSS 1 Hale-Bopp, **5** Areola, **9** Lancelet, **10** Argali, **12** EPROM, **13** Universes, **14** Evolve, **16** *Arrival*, **19** Chronic, **21** Cohort, **23** Diaphragm, **25** Wilco, **26** Shrink, **27** Duodenum, **28** Spasms, **29** Sturgeon

DOWN 1 Halves, **2** Land Rover, **3** Bream, **4** Prepuce, **6** Rare earth, **7** Ovals, **8** Acid salt, **11** Mica, **15** Lanthanum, **17** Virulence, **18** Acidosis, **20** Coal, **21** Combust, **22** Zoom in, **24** Atria, **25** Wider

#220 Artificial Intelli-Vision song contest
Solution

Eight countries took part and the winning song scored 36 points.

If there are N countries, each judging panel gave scores to N-1 songs, and the score of 10 was then deducted, so the 222 total points = (number of countries in the final round - 2) x the sum of each different number that the panels chose. No countries tied, so there are at most nine different countries. Since the factors of 222 are 2, 3, and 37, there must have been eight scores (from eight countries) that added to 37.

We know one score was 7 points, and the only combination that adds to 37 is 9,7,6,5,4,3,2,1. The best musical act must have scored 37-1 = 36.

The Kármán sutra

"Sex in space: Consideration of uncontrolled human conception in emerging space tourism" is a paper written by David Cullen at Cranfield University in the UK, in collaboration with sex-in-space enthusiasts in the US, the Netherlands, Brazil and Austria. It is stimulating much discussion.

The paper is almost Victorian in its voluminous discussion of possible regulatory mechanisms, but nearly complete avoidance of mentioning fornication. The highest moment of titillation comes in the following passage: "The adult film industry has previously explored the possibility of video/film production in space environments. In 2000 a parabolic aircraft flight was used for filming a weightless scene…"

The authors explain that they created the document "to encourage and contribute to a broad actor and stakeholder engagement and discussion".

Feedback offers further encouragement by mentioning a somewhat related paper written in South Africa in 2009. It is called "'Sex, sun, soccer': Stakeholder-opinions on the sex industry in Cape Town in anticipation of the 2010 FIFA Soccer World Cup".

Like "Sex in space", "Sex, sun, soccer" looks at people who just want to get together. The old paper, like the new one, gives close attention to opinionated experts. In it, one of those experts seemingly spoke to the spacey future, as well as to the soccer-y, sex-and-sun-drenched milieu of 2009:

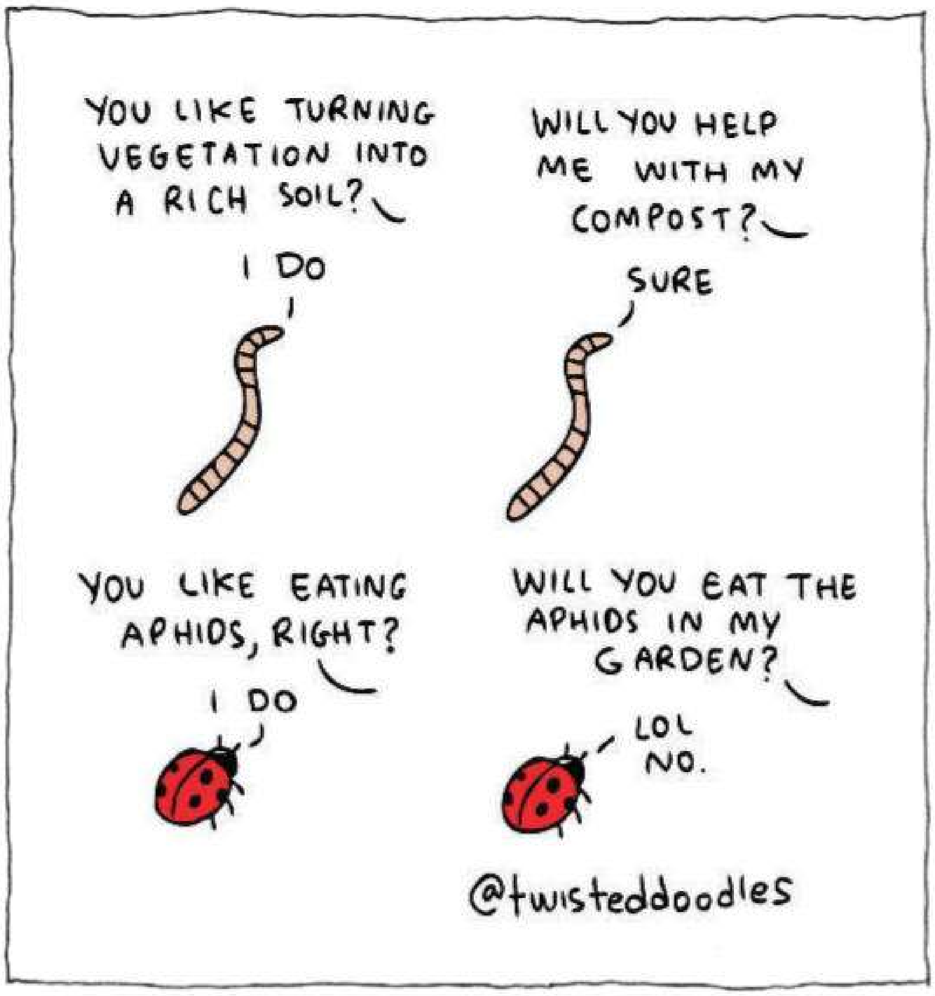
"Most vocal has been the now suspended South African Chief of Police, Jackie Selebi, who urged the National Assembly's Safety and Security Committee to consider the reality of the thousands of soccer fans expected to overrun the public sphere and satisfy their urge to try out more exotic pastimes".

The new, "Sex in space" paper from Cullen and his colleagues echoes Selebi's thought, saying that "it seems unrealistic to assume that all space tourism participants will abstain from sexual activities whilst in space and exposed to space environments".

Sadly for all concerned, *The New York Times* reported on 23 January 2015 that Selebi, "who in 2010 was convicted of taking bribes from a drug trafficker in a trial that drew immense international attention, died on Friday in a Pretoria hospital".

Perhaps Cullen and his "Sex in space" co-authors can seek advice from another South African figure, the rocketry and money enthusiast Elon Musk.

Twisteddoodles *for New Scientist*


YOU LIKE TURNING VEGETATION INTO A RICH SOIL?
I DO
WILL YOU HELP ME WITH MY COMPOST?
SURE
YOU LIKE EATING APHIDS, RIGHT?
I DO
WILL YOU EAT THE APHIDS IN MY GARDEN?
LOL NO.
@twisteddoodles

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Consideration of items sent in the post will be delayed

Love thy crank

Many scientists enjoy an unsteady supply of letters sent to them by eccentrics. Many scientists don't enjoy it.

People at the RationalWiki have been gathering and tending a list of what they regard as "cranks". From a neuroscience action-potential perspective, and perhaps from other perspectives, too, here are some of the standout items:

"Andy Kadir-Buxton – slapping people on the head to cure mental illness";

"John Brandenburg – the 'thermonuclear war on Mars' guy";

"Richard Shaver - Subterranean cities and their malevolent inhabitants, the Dero";

"Aleister Crowley – Magic powers, demon and angel summoning, being the Great Beast 666".

Feedback presumes that list includes a small number of mistakes and a vast sea of omissions. And that some of the entries were written by "cranks".

The world, with its approximately 8 billion human inhabitants, is numerically cruel. Only a very small percentage of the population ever gains international notice of any kind.

Accordingly, if you, dear reader, find yourself included in that "cranks" list, Feedback offers you hearty congratulations on being recognised, however incorrectly, correctly or unfathomably.

To be sniffed at

The desire to "wake up and smell the coffee" drives many people. In the science community, that drive is notoriously and proudly strong. A Belgian/Italian/Argentinian collaboration is souping up the available technology for smelling coffee, some details of which appeared recently in *Analytical and Bioanalytical Chemistry*. In their words, these collaborators are "exploring different high-capacity tools and extraction modes to characterize the aroma of brewed coffee". Others, elsewhere, are working with the same aim and enthusiasm.

Coffeetechnosniffistas abound. Many of them are joyful and eager to make friends. In the great tradition of tinkerers who brought the world reliable automobiles, airplanes, radios, computers, digital keyboards and social media apps, they talk in a jargon that outsiders might struggle to understand. But there is no need to feel intimidated. Curiosity, when combined with coffee, can lead to friendship and enlightenment.

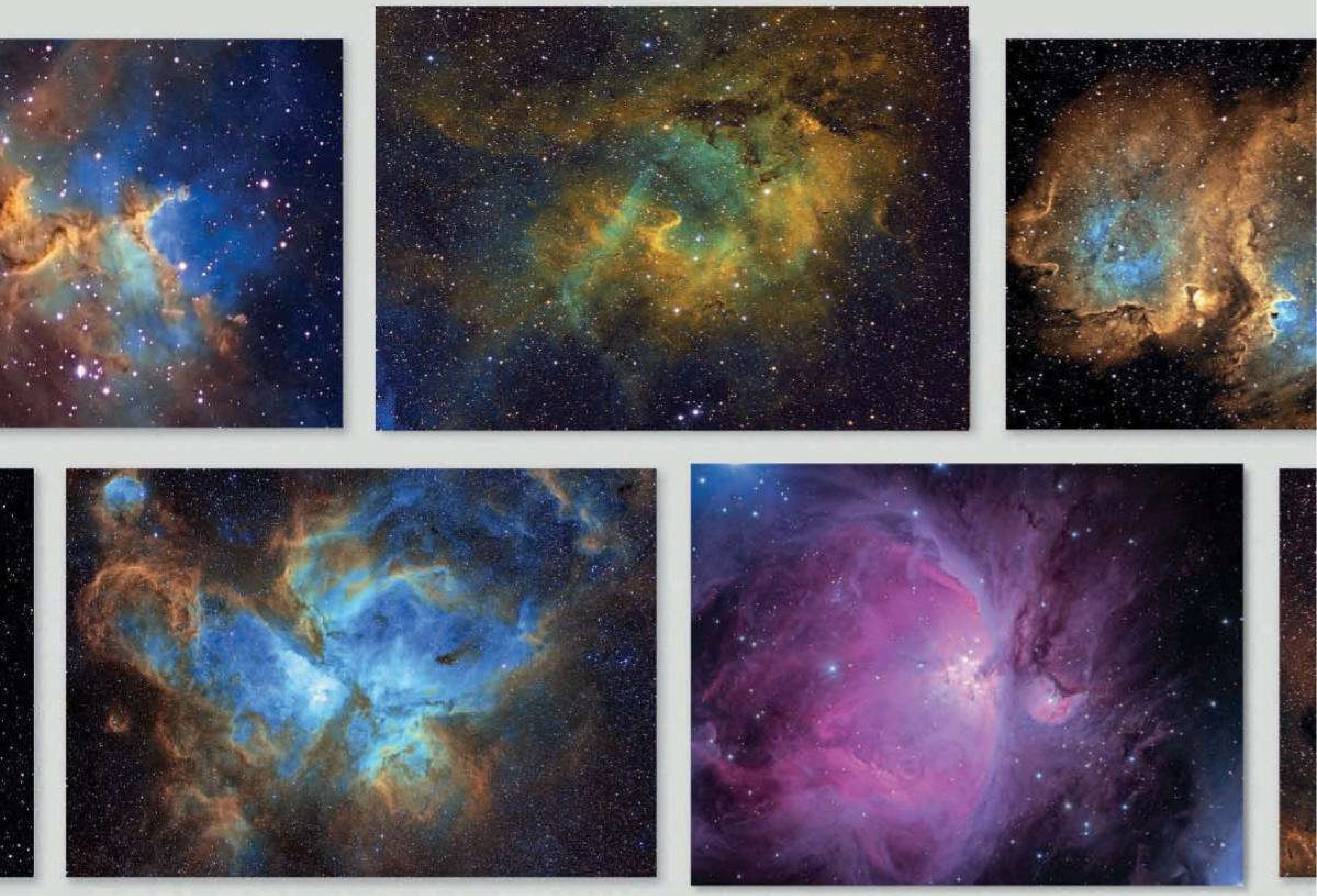
Anyone who really does want to know more can take an easy first step. When visiting any coffee shop, be on the listen out for chitchat that sounds like this: "multi-cumulative trapping headspace extraction was explored by comparing the results using solid-phase microextraction coated with divinylbenzene/carboxen/polydimethylsiloxane and a probe-like tool coated with polydimethylsiloxane".

When you hear it, bring yourself, and a smile and a cup of coffee, over to the chitchatters' table and say: "I'd love to learn how this stuff works." ■

Marc Abrahams

GALAXY
ON GLASS

SPECTACULAR WALL ART FROM
ASTROPHOTOGRAPHER CHRIS BAKER



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